HOUSE ORGAN OF Q-ALLOYS GENERAL ALLOYS COMPANY

EDITED BY H. H. Harris PRESIDENT

ALLOY PROGRESS

Bright Spot in Metal Progress

ENTIRELY ABOUT HEAT & CORROSION RESISTANT ALLOY CASTINGS

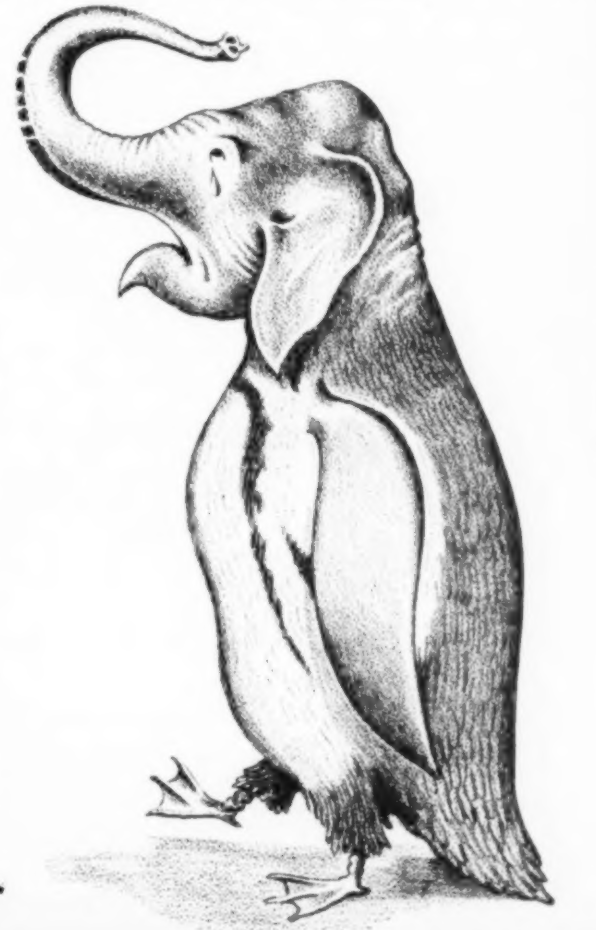
The EAGLE-ASS *and the* ELEPHLOP

(With apologies to Chaucer, Chick Sale and Al Smith.)

THE Ostrich is thought the oddest of birds, his parentage split into questionable thirds, with Giraffe, one-third, and a third Wild-Turkey, his Love-life-line is excusably jerky. But, he can't hold a candle, a spark in the dark, to the Prize miscegenation of Barnyard or Ark, the Zoo-illogical Pousse-cafe that heralds the dawn of a "Brighter day."

YOU'D never dream it could come to pass,—but,—Voter,—meet the EAGLE-ASS.

THE American Eagle, from legend old, his image on verboten gold, is just a childhood fantasy like the "Home of the Brave and the Land of the Free," a



of Horse-and-Buggy Days when people believed "the Woman pays."

...E soaring Eagle's wings are folded, as he broods ... the shame of a bird Cuckolded.

...ES, things have come to one Hell-of-a-pass when ...ur National Bird is an EAGLE-ASS.

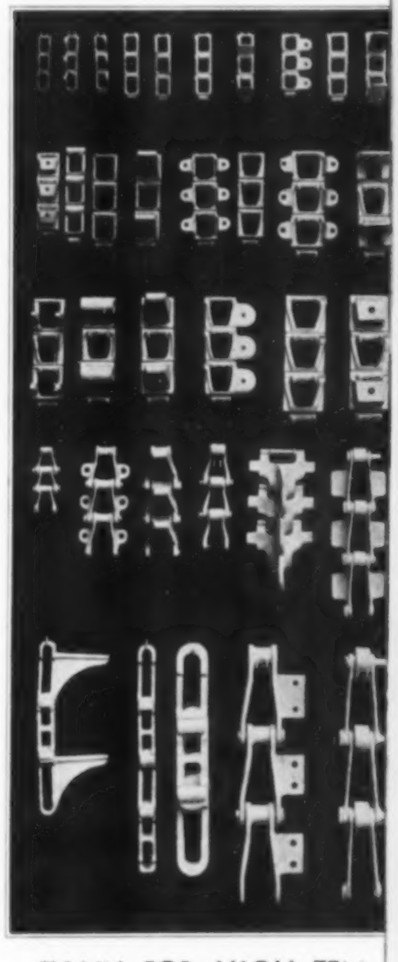
...ST we be rated "Kulaks" and taken for a ride, ...we'll flip this phoney coin, and show the other ...

...OU'VE seen the "Head," the EAGLE-ASS, now gaze ...pon the "Tail," and view another love-child, ...e virtue's grown stale.

...E ELEPHLOP, we now present, the son of G.O.P., ...a Penguinated Pachyderm, a DODO-Bird is he. ...'d expect a romance this absurd, when voters gave ...P. the "Bird.")

...LITICS, smells bad at top, but as you start to drag ... the scum-de lá- scum that turns the wheels would ...a self respecting maggot. We shed no tears for ...PHLOP, or cheers for ...LE-ASS, but roundly ... all Demagogues who ...d set class on class.

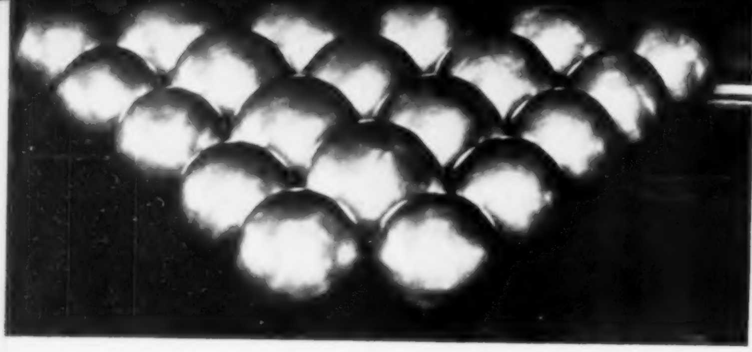
H. H. Harris



CHAIN FOR HIGH TEMPERATURE & CORROSION

THE types of chain shown above are but a few of the widely diversified designs running from five ounces to forty pounds per foot and handling everything from mower blades to cast iron pipe that are available in Q-Alloy and X-ite for temperatures to 2300° F.

Cast Stainless Steel chain is made to these and other designs.



HOLLOW STAINLESS BALLS

THESE balls are made from one inch to fourteen inches in diameter of Q-Alloy CN-1 and are used in ball valves, in oil lines and the like. They are ground to .0002". Unequalled General Alloys foundry practice.

GREATEST OF ALL STEEL SHOWS

THE nineteenth National Metal Exposition will be held in Atlantic City's new Exposition Hall, the finest in the world. The exhibits and attendance will break all records. There is so much new stuff that you can't afford to miss it.

SALEM ENGINEERING

Proven Pusher Furnace

THIS double chamber pusher type annealing furnace was one of Salem Engineering's first jobs and it has an excellent record of economy and performance.

THIS furnace is equipped with X-ite rails and X-ite hinged trays.

THIS type of tray annealer can handle a variety of work. It can also be supplied with controlled atmosphere and controlled cycle, gas, oil or electrically heated.

AUGUST, that hot month when the June brides have that well-groomed look. If you haven't read Walter Chrysler's "Story of an American Workman" in the *Saturday Evening Post*, you've missed something.

UNPLEASANT sensation, when you fly into a landing light that makes a whirling propeller look like a stone wall.

A Stainless Steel "Stick" in my Fairchild eliminated all the bad effects of the former steel stick on the compass. All airplanes should have S.S. Sticks.

R. F. BENZINGER, president of Electric Furnace Company, is an engineer even at play where he works out problems in navigation to stop watch precision on his sea-going schooner, "Norbador." One of the most sea-worthy packets of her size afloat, the "Norbador" should win the Mackinac race on time if her skipper can ever get time off to sail her. My advice to him is to *take* the time. When I had the Mindoro on the lakes, I was "too busy" alloying around to sail her, the answer to which is "nutz."

MANY steel treaters and Illinois graduates know George Franks, former mayor of Champaign. George delivered his son and heir, Thomas, to the tender mercies of G. A. The young man with the seductive smile, the big feet and the bonnet is now a full fledged G. A. metallurgist and is shown upper right, page three, explaining things.

JOINS BOSTON STAFF

TESTIMONIAL to a Bone Surgeon: "Say, Allerton, who was that bow-legged girl I saw you with today" . . . . "Oh,—Walter, —don't you remember her,—she is the knock-kneed girl you met two weeks ago."

MAJOR went to another dog show, knocked off first in American Bred Great Danes, and was all set to knock off the show when some purp swore at him, they tangled and the Judge tossed them both out of the show.

AN old lady remarked, "Mister, i[illegible] goin' to board a beast with suc[illegible] tite I'd keep one as could be milke[illegible]

IF you are considering a conveyor [illegible] moving hearth furnace, don't [illegible] of those stretch-screen chicken-wire [illegible] it, specify a SPIRALINK cast X-ite b[illegible] you won't be sitting up nights tak[illegible]

R. F. BENZINGER'S "NORBAD[illegible]

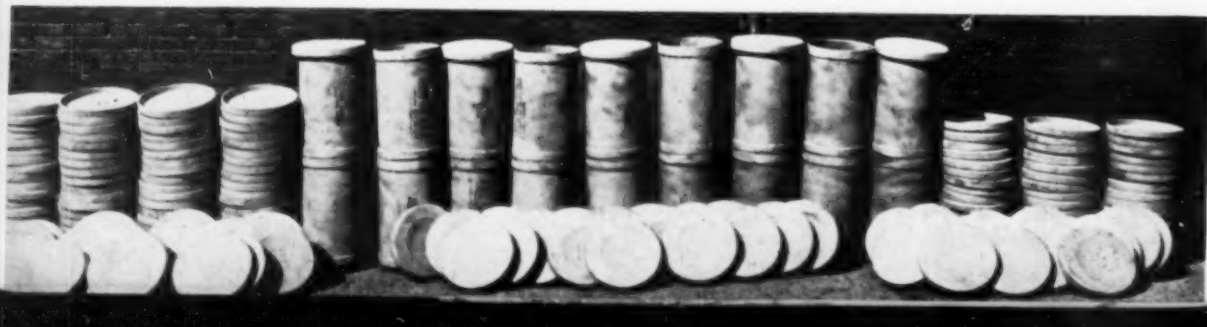
the slack as the thing stretches from [illegible] breakfast, for SPIRALINK stays [illegible] costs far less per-heat-hour-of-servi[illegible]

SCOTT-HUGHES, of *The Times*, [illegible] is at Newport covering the Inter[illegible] Yacht Races, intercepting for T.O.[illegible] with, and writing a book (which he [illegible] to illustrate with my aerial photogr[illegible] the races), flew with the Royal Flyin[illegible] in the war, and later in India. His [illegible] always slept without his mosquito [illegible] for "The first half of the night he [illegible] drunk to feel 'em, and the second h[illegible] were too drunk to bite him."

Hughes' impressions of America: [illegible] York,—where they put up the mone[illegible] cago, Detroit, Pittsburgh, where th[illegible] the game. Washington, where they [illegible] with the rules."

SOON, we will announce a chain w[illegible] two pounds per foot, with 1¾" [illegible] pitch, and pulling approx. 10,000 lb[illegible] or slightly better than the best sho[illegible] chain weighing 3½ lbs. per foot. Th[illegible] has 95% of its mass in tension, an[illegible] better than 90% of theoretical desig[illegible] nace Engineers, Furnace Buyers, no[illegible]

(Continued on page 4)




General Alloys Company
WHOOPS!
Outing
STOW COUNTRY CLUB
All of these folks are Agreed that—
Alloy Parts
Just a little Bull at the Party
THE QUALITY NAMES IN ALLOY
FOR HEAT CORROSION ABRASION
Q-ALLOYS
X-ite
Hello, Steel Treater— Meet the General Alloys Gang at play— See the Youth and Vitality that Keeps this outfit as far ahead of the pack as Mae West has been leading her husband. Here are 50 good reasons why General Alloys is Going Places! —Your Announcer
RALPH HARE — N.E. Sales Manager
Well, here's Old General Alloys About to Celebrate a 20th anniversary — the Oldest and Largest Exclusive manufacturer of Heat and Corrosion Resistant Alloys — and we are all most thankful to our Customers! — Van
Q-ALLOYS
To Be Sure
RUPPERT

No furnace is better than its Alloy Par

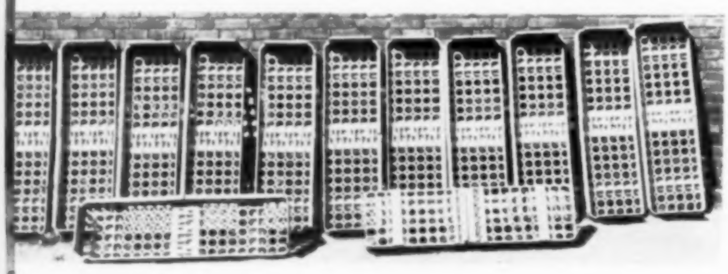
Rockwell Furnace Does Bright Annealing on Fuel Gas

THIS furnace is a very unique unit in that no additional gas other than that required for firing the furnace has to be used for the development of the protective atmosphere.

NO turned down ends with inclined belt sections are employed, with the result that long length, straight pipe or coiled service tube can be run through the furnace intermittently without change of handling method.

UNUSUAL and highly effective means are provided for forced cooling, requiring short cooling section with high furnace output. This saves overall length and plant space.

THE output is from 1000 to 1500 pounds per hour with a total gas consumption with less than 1 cu. ft. per lb. on the basis of 530 b.t.u. gas handling copper. This furnace also handles cupro-nickel tubes. Tubes with unusually high finish are produced and "even dirty tubes can be put through and cleaned up."



Hinged Trays Do the Job Cheaper and Better

THE above trays are a few of thousands of our patented Hinged-Trays which provide *flexibility, save weight, save fuel and handling and prolong life.* If you are using rigid trays you are *throwing away money.*

THE WORLD ADMIRES A FIGHTER

WHATEVER your politics, you must admit that Tom Girdler had guts enough to battle for his convictions and, incidentally, for the convictions of a lot more people in overalls and shirtsleeves than some politicians believe.

THOMAN, G. A. artist, made this sketch of Tom Girdler. If you would like one, 8 x 10, suitable for framing, write on your letterhead.

TOM GIRDLER

(*Concluded from page 2*)

HIRONDELLE, world famous Yacht of the Prince of Monaco, almost created an international incident on her first visit to Boston. She had been at sea for months on oceanographic exploration, and the crew itching for land cheered when Boston light hove in sight. Steaming nearer they sighted Bumpkin Island, then the site of a girl's reformatory. It was a Monday morning, and 300 pairs of maidenly pants were hanging on the wash line. Appropriately, modestly, he still maintains, Hirondelle's Commandante fired a 21-gun salute. Coast Artillery lookouts reported a bombardment, and there was hell-to-pay generally.

THERE has been enough alloy "grief" in the last year with broken down roller rails, warped and cracked trays, conveyor hearth failures in large furnaces bought by big users from established furnace builders to have justified the payment of the slight extra cost of X-ite many, many times over. "NO FURNACE IS BETTER THAN IT'S ALLOY PARTS."

IF you plan to buy new furnaces, call in a General Alloys Engineer and decide which type of alloy mechanism will serve you best. If you specify General Alloys parts you can be certain that you're not a guinea pig for some "cheap" alloy after that one year furnace guarantee expires, or even before.

MR. SCHAINES, of Dyke & Schaines, G. A. Patent Counsel, while attending the Coronation, fancied the large ornamental British Lions, some five feet in height which surmounted posts along the Line of March, so, being an old time hotel towel and Pullman blanket collector,—*presto-change-o*,—and three lions arrive in N. Y. One to adorn the garden of Mr. Dyke at Larchmont.

WHEN you come East on vacation be sure to include Sunset Inn at Sugar Hill, New Hampshire, look up Steward Peterson, who recently left us on the Yacht Guardian after three years of loyal service to take a better job. Peterson puts out his best for Steel Treaters. Succeeding Peterson is Satya who comes from India where the sit-down strike started in diapers, via Columbia University, graduating in Political Science. (So, it's a science, we thought it was a disease). I'm bringing Satya some Q-alloy facing sand to pop rice in Indian style. If it works, we'll spill the recipe.

MOST IMPORTANT THING IN THE WORLD

By R. B. BURWELL

I AM the most important thing in the world. Without me business would fail, nations crumble and civilizations vanish from the Earth. Although I appear in many forms I am ever present and no one can escape me. I dwell in both the highest and the lowest places and am closer to you than your shadow and infinitely more realistic. I treat all people alike, the rich, the poor, the great, the small, but what *you* are depends on how you have treated me. Treat me kindly and I will reward you with power beyond your wildest dreams. Mistreat me and you will plunge yourself into the nethermost depths of eternal misery for I cannot be bargained with or met on any basis but my own. Therefore, it is to your advantage to do well by me, for in just such proportion will I reward you. This is truly so, for to me all things are possible. No imaginings are too fantastic for me to make them true, no demands upon me too great for me to answer, and if you give me your all, of a surety will I reciprocate, for I am the physical incarnation of the Fairy Godmother of all men's Desires. I am YOUR job—*whatever* that may be.

Help Yourself

to this

HELPFUL LITERATURE

Juthe Pot Furnace

Juthe gas-fired pot furnaces are designed for drawing, hardening, liquid carburizing, and reheating. The cylindrical type, Model GP, is fully described and standard sizes given in a leaflet by American Electric Furnace Co. Bulletin Ha-2.

Alloyland

Reprints of "Alice in Alloyland," the whimsical, cleverly written little parody of Lewis Carroll's classic published in Metal Progress, have been prepared by Electro Metallurgical Co. and are available for distribution. Bulletin Ha-16.

Flowmeters

Flowmeters patented by American Gas Furnace Co. measure the entire flow of air or gas, thus permitting exact control of gas burning operations and carburizing. The principle, installation and uses are described in Bulletin Ha-11.

Staybolts

With higher speeds, greater loads, and increasing boiler pressures, locomotive staybolts have a tough job these days. Information on Bethlehem Steel Co.'s Mayari staybolt steel should therefore be of interest. Bulletin Ha-76.

Hy-Speed Case

50 to 500% increase in the life of high speed steel tools is claimed in a striking and interesting new booklet just published by the A. F. Holden Co. Typical cases of these savings are cited. Bulletin Fa-55.

Testing Equipment

Fully illustrated, complete with charts, curves and other technical data, containing 48 pages, and in two colors throughout, the new Testing Machine Bulletin issued by the Baldwin-Southwark Corp. containing a comprehensive description of the well-known Southwark-Emery line of equipment should be a valuable addition to any library. Bulletin Ha-67.

Sawing and Cutting

"The Do-All Digest" is an interesting little publication of the Continental Machine Specialties, Inc., giving pertinent facts about the Do-All line of cutting machines. It is illustrated, showing examples of work done. Bulletin Ha-170.

Small Pyrometers

Because of their low price and easy installation, Wheelco Instrument Co.'s small indicating pyrometers may be used wherever temperatures need checking. Described in Bulletin Ha-110.

Magnet Steels

A very handsome booklet describes the permanent magnet steels and castings made by Simonds Saw & Steel Co., including Alnico and Alnic. Bulletin Ba-158.

Dental Metallurgy

A unique publication by International Nickel Co. details information on mechanical properties, heat treatment and working instructions for the platinum-palladium-gold alloys extensively used in dentistry. 36 pages; large size. Bulletin Ha-45.

Tooling Costs

Why shielded arc welding is ideal for tooling is told in "A Guide to Lower Tooling Costs With Shielded Arc Welded Steel Jigs and Fixtures," published by Lincoln Electric Co. Typical welded steel jigs and fixtures are illustrated and described. Bulletin Ha-10.

Annealing Practice

A very well printed and bound booklet by Surface Combustion Corp. is unique in that it illustrates both by photographs and blueprints six different forms of radiant tube annealing covers for sheet, strip, rod and wire. Manufacture of the prepared atmosphere is also described. Bulletin Ha-51.

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-169.

Metallograph

Leitz Large Micro-Metallograph "MM-1" — most interesting 36-page publication containing numerous photomicrographs on the very latest developments in metallographic equipment. Special attention is given to darkfield illumination. Bulletin Ha-47.

Grinding Carbides

A complete and detailed treatise on this important problem has been issued by the Carborundum Co. Special wheels and grits for the various commercial grades of carbides are given and many practical pointers are included. Bulletin Nv-57.

Photoelectric Balance

C. J. Tagliabue Mfg. Co. has christened its newest, simplest and fastest recording potentiometer the "Celectray" from the photocell, electric current and light ray by means of which it operates. Described in Bulletin Ea-62.

Spoilage Fear

Fear of spoilage, says C. I. Hayes, Inc., may cost a firm more than actual tool loss through spoilage in the furnace. How "certain curtain" furnaces eliminate spoilage and spoilage fear is told in Bulletin Aa-15.

Protection Tubes

The advantages of a die cast over a sand cast pyrometer protection tube are described and illustrated by Driver-Harris Co. Stock sizes of Nichrome protection tubes are listed. Bulletin Ga-19.

Metals for Corrosion

Fourteen varieties of Midvaloy corrosion and heat resisting metals are described in a detailed bulletin by The Midvale Co. Properties and applications are listed and illustrated. Bulletin Ca-160.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Tube Furnaces

The uses, construction, control and operation of combustion tube furnaces are given in a folder by Hevi Duty Electric Co. which includes complete specifications for various types. Bulletin Aa-44.

Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Hardening Furnaces

P. D. M. high speed hardening furnaces are described in two bulletins by The Philadelphia Drying Machine Co. — one devoted to oil-fired and one to gas-fired furnaces, both made in single and twin chamber models. Details of construction, design features and tables of sizes and capacities are included. Bulletin Oy-150.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Division of Carborundum Co. Bulletin Oy-25.

Hot Work Steel

A new "Blue Sheet" by Ludlum Steel Co. gives physical properties, comprehensive test data and recommendations for heat treating Atlas A hot work steel, a tough, shock resistant tungsten steel. Bulletin Fa-94.

Bolts and Nuts

The calorizing process of driving aluminum into the surface of steel and the physical properties of bolts and nuts made from calite alloys are described in a folder by the Calorizing Co. Bulletin Fa-26.

Oxidation

Designers confronted with oxidation problems connected with cracking coils, polymerization plants, superheaters, high pressure steam plants, air heating equipment and recuperators will welcome a folder by Timken Roller Bearing Co. containing data on oxidation at 1000, 1250 and 1500° F. Bulletin Ea-71.

X-Ray Examination

The application of X-ray examination and inspection of castings, welding, and food products, as well as practical X-ray crystal analysis, is completely described and strikingly illustrated in General Electric X-Ray Corp.'s new 34-page publication. Bulletin Dy-6.

Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Stainless Tubing

A folder full of helpful technical data on the properties and use of welded stainless steel tubing, a product finding many new applications, is offered by Carpenter Steel Co. Bulletin Oy-12.

Firebrick

Babcock & Wilcox make an insulating firebrick which is refractory as well as insulating and can be used without a facing of firebrick. Description, applications, and engineering data are contained in Bulletin Fy-75.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

Meehanite

A compact but complete specification chart gives the recommended grades of Meehanite metal for various service requirements. Complete physical properties and applications are included. Bulletin Da-165.

Mesh Products

Wire mesh is a class of material about which little is heard. A folder by C. O. Jelliff, therefore, telling the special alloys and metals used, styles of weaves and applications is of unique interest. Bulletin Do-78.

Alloy Steels

Why alloy steels are best for heavy equipment and other exacting applications is discussed in a folder by Bliss & Laughlin, Inc. A partial list of the more common grades gives machine ratings and turning speeds. Bulletin Jy-42.

Cutting Steel

Recommended practices for gas cutting of structural steel are given in a concise and authoritative form by The Linde Air Products Co. Qualification tests for good workmanship from the standpoint of accuracy and smoothness of cuts are also described. Bulletin Dc-63.

Some of the Best Thinking

in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.

Heat Treating

A folder by Industrial Heating Equipment Co. explains and illustrates diagrammatically a continuous type heat treating furnace in which temperatures can be held to within extremely close limits, and in which the product is always uniformly heated. Bulletin Ga-168.

Sheet Metal Guide

If you work with sheet metal you will be sure to want this 63-page booklet by United States Steel Corp. It is chock-full of helpful hints and useful practical information on galvanized, black, terne, and stainless steel sheet. Bulletin Ga-79.

Optical Aids

Bausch & Lomb's new catalog lists and describes the instruments and accessories that are especially useful in the metal working industries, such as the toolmakers' microscope, the wide field binocular, the shop microscope, and the Brinell microscope. Bulletin Ga-35.

New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnaces Co.'s new, inexpensive non-oxidizing furnace atmosphere and their new, continuous brazing, coppering and soldering furnaces. Full details are given in Bulletin Ar-30.

Hump Hardening

All three vital factors in correct hardening are completely controlled by the new Vapocarb Hump method of hardening, which is well described in a Leeds & Northrup bulletin. The three factors are: Quench point, rate of heating, and furnace atmosphere. Complete details are given in Bulletin No-46.

Chapmanizing

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Grinding Lubrication

A handy outline for the selection of grinding wheels is one of the useful features of a booklet full of facts about grinding solutions. D. A. Stuart & Co. Bulletin My-118.

Vanadium Facts

Revived after nearly 20 years is the house organ of Vanadium Corp. of America, "Vanadium Facts." This paper shows considerable thought and care in its preparation and contains valuable and interesting information on vanadium steels. Bulletin Ox-27.

Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Metal Surfaces

A manual giving in detail methods for the application of sodium cyanide solutions in the preparation of metal surfaces is announced by the R. & H. Chemicals Department, E. I. du Pont de Nemours & Co. Bulletin Ba-29.

Blast Cleaning

So many changes have taken place in blast cleaning and dust collecting equipment in the past three years that Pangborn Corporation's "quick reference" catalog of condensed information will be invaluable to all those interested in this subject. Bulletin Jy-68.

Chain

Interesting information on chain and belt conveyors for use at high temperature may be had by sending for a new illustrated bulletin by Michigan Steel Casting Co. Bulletin Dy-84.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Refractory Blocks

Light-weight, low heat storage insulating refractory blocks known as "Insulblox" for reducing heat storage and radiation losses at operating temperatures up to 2200° F. are described in a folder by Quigley Co. Bulletin Ea-139.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Alcoa Notes

"Alcoa Random Notes" is the intriguing title of a little monthly paper got out by Aluminum Co. of America. A request for this bulletin will bring you a copy of the latest issue. Bulletin Ca-54.

Steel Handbook

A veritable handbook is Jessop Steel Co.'s catalog of carbon, tool, stainless and other alloy steels. Descriptions are supplemented by instructions for forging and heat treatment, and diagrams and charts of physical properties. Bulletin Ha-61.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue—Bulletin Ax-4.

Copper Bulletin

A new clearing house for news of developments in brass, bronze, and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

Turbo-Compressors

Spencer Turbine Co. has turbo-compressors in all sizes and types for oil and gas-fired furnaces, ovens and foundry cupolas. Special types for special purposes such as gas-tight and corrosion resisting applications are also described in Bulletin Da-70.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Laboratory Service

A new edition of "The Metal Analyst" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Arc Welding Future

Harnischfeger Corp. takes a look at the future of arc welding in a booklet stressing the simplicity of "Smootharc" welders. Illustrated with a wealth of photographs, drawings and cross-sections. Bulletin Ha-171.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Photo-Electric Cells

If your are not familiar with the wide field of applications for photo-electric cells and apparatus, send for this very interesting and complete booklet by Pfaltz & Bauer, Inc. covering the original apparatus developed by Dr. Bruno Lange. Bulletin Ca-142.

EPI Microscope

The Zeiss EPI microscope for the illumination and observation of opaque material has unlimited applications for observing opaque material in dark field, bright field, and polarized light. A descriptive leaflet is published by Carl Zeiss, Inc. Bulletin Aa-28.

Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Metal Progress,
7016 Euclid Avenue, Cleveland, O.

Send me the literature circled below.

Name ....

Title ....

Company ....

Company Address ....

Numbers are listed in the same order as the literature described—circle the numbers that interest you. It is important to write in your company or business connection when you return this coupon.

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Ha-2	Ha-45	Ca-100	Dy-6	Ga-168	Ox-27	Ca-54	Ha-171
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Ha-11	Ha-51	Aa-44	Oy-12	Ga-35	Fx-66	Ax-4	Ca-142
Ha-76	Ha-169	Oy-147	Fy-75	Ar-30	Ba-29	Da-163	Aa-28
Fa-55	Ha-47	Oy-150	Ea-5	No-46	Jy-68	Da-70	Oy-138
Ha-67	Nv-57	Oy-25	Da-165	Ob-80	Dy-84	Jy-125	Jy-127
Ha-170	Ea-62	Fa-94	Da-78	Ar-64	Ar-49	Dy-135	Fx-32
Ha-110	Aa-15	Fa-26	Jy-42	Ob-24	Ea-139		
Ba-158	Ga-19	Ea-71	Dc-63	My-118	Je-33		

ANNEALING OF NICKEL SILVER

By Maurice Cook

Abstracted from advance copy of Paper No. 721, Institute of Metals

To OBTAIN some order out of a bewildering variety of compositions, the British Standards Institution has suggested a limitation to alloys containing 60 to 65% copper, nickel either 10, 12, 15, 18, 20, 25 or 30 (plus or minus 1%) and remainder zinc. The test samples described in this paper were rolled from 50-lb. ingots made in cast iron molds, and the copper was between 62.0 and 62.6%.

In the annealed condition (0.300-in. strip) as well as in the lightly worked condition, the hardness increases with the nickel content, being Vickers 140 for 10% nickel and 170 for 30% nickel after 20% reduction in thickness. The curves showing the hardness versus reduction of the various alloys cross at about 50%, and at 90% the order is reversed from that at the start, the 30% nickel then being softest (220) and the 10% hardest (245).

The relation between diamond penetrator and Brinell (10-kg. load, 1-mm. ball) is

$$D = 1.2\ (B - 10).$$

As in the case of hardness, the tensile strength values show that the increase resulting from 90% reduction in rolling is greater for the 10% nickel alloy than for the 30% alloy. The tensile strength of the 10% nickel alloy was 49,500 psi. in the annealed condition and 125,000 psi. after a reduction of 90% by cold rolling, the corresponding values for the 30% nickel alloy being 55,500 and 109,000 psi. respectively.

For all these alloys the elongation decreases rapidly during the early stages of cold work, but the decrease in values for reduction of area is much more gradual and even after reductions in thickness of the order of 80 and 90%, when the elongation values are extremely small, the original figures for reduction in area were only reduced by about one third.

Limit of proportionality and proof stress values are similar for the three alloys and the effect of cold work on these properties is not appreciably different. The average figures for modulus of elasticity, based on ten determinations, are 17,800,000, 19,600,000 and 21,300,000 psi. respectively for the three alloys containing 10, 18, and 30% nickel.

The degree of hardness corresponding to half-hard, hard, and *(Continued on p. 194)*

ANNEALING OF NICKEL SILVER

(Continued from p. 192) extra hard tempers is obtained by rolling reductions on material in the annealed condition of about 20, 35, and 60% in thickness, respectively. Samples of strip of all seven alloys were produced in these three conditions, and small specimens cut from the strips were annealed at different temperatures for half an hour. When these results are plotted, the curves show that the temperature at which softening occurs increases slightly with increasing nickel content. For example, the Vickers hardness of the 10% nickel (originally 135 after 20% reduction) is 127 after annealing at 400° C. (750° F.), 115 after annealing at 500° C. (935° F.) and 80 after annealing at 600° C. (1110° F.). Corresponding figures for the 30% nickel brass (originally 158) are 163, 150 and 131; annealing at 700° C. (1290° F.) is required to reduce the hardness to 93.

All alloys harden slightly after low annealings; in general this hardening amounts to 2 to 5 Vickers numbers at low reductions, but may reach 14 points in low nickel alloys heavily cold worked and annealed at 300° C. (575° F.).

This information on the annealing characteristics as shown by hardness results has been supplemented in the case of alloys reduced 60% in thickness by cold rolling by determining the effect of annealing temperature for half an hour on tensile strength, elongation, and Erichsen values of strip 0.069 in. thick, from which it is again evident that the softening temperature increases with the nickel content. When plotting the curves of properties versus annealing temperatures (annealed after 60% cold reduction) the one for Erichsen value parallels the one showing per cent elongation.

After similar conditions of cold working and annealing the resulting grain size decreases with the nickel content. Thus, for example, it was found to range from 0.06 mm. to 0.03 mm. in the 10 and 30% nickel alloys, respectively, after a cold rolling reduction of 40% followed by annealing for 2 hr. at 800° C. (1475° F.).

Values for other physical properties are also given. Density increases with nickel content, being 8.609 annealed and 8.621 cold rolled for a 10% nickel brass, and 8.868 annealed and 8.880 cold rolled for a 30% nickel brass. Specific electrical resistance also increases markedly, being 20.71 and 37.89 microhms per cc. respectively.

CASTING OF METALS

(*Cont. from p. 144*) Eutectic alloys, and such as occupy a minimum on the freezing point curve, freeze at a constant temperature, like pure metals. Portevin and Bastien have concluded, from a study of a number of alloys of low melting point, that the flowing power varies (in any one system of alloys) inversely as the solidification interval, and is thus greatest for pure metals and eutectics. This has been confirmed by other workers.

Experiments have been extended to ternary alloys and it is found, as might have been expected, that a ternary eutectic, which freezes at a constant temperature, has the greatest flowing power of all the alloys included in the system. Once more the flowing power is (roughly) inversely proportional to the range of temperature over which solidification takes place. The conclusions are in accord with the observed behavior of phosphoric cast iron, which is well known to be more fluid than a similar iron containing less phosphorus.

The reason is to be found in the separation of the primary crystals, which form a shell obstructing the flow. The "habit" of the crystals affects the resistance which they offer, and alloys with a long freezing range mostly deposit primary crystals of the dendritic type. When the interior of the mold has been coated with crystals of solid metal, the volume of liquid which traverses the constricted channel in unit time, being proportional to the fourth power of the radius, will fall off very rapidly as the thickness of the solid layer increases. Moreover, should the crystals formed be dendritic, projecting into the interior, they will have a greater effect in retarding the flow than if they were simple polyhedra. Pure metals and solid solutions crystallize mainly as dendrites, while intermetallic compounds are more often polyhedral, and eutectics tend to form spherulitic masses, which probably offer the least resistance of all.

Crystal Thrust — A factor which is commonly ignored is that of the thrust which may be exerted by growing crystals. An apparent expansion during solidification is sometimes observed when determinations of density show that the volume has actually diminished. When plaster of paris is mixed with water in a test tube, the mass seems to expand during setting, and the glass will burst. The volume after setting is, however, less (*Continued on page 198*)

CASTING OF METALS

(Starts on page 144) than that of the original plaster plus that of the water. The effect is due to the crystals pushing against one another, and increasing the apparent volume, the resulting mass being porous. In the same way, with the modification of Keep's contraction apparatus, in which the metal is cast in a sand mold in the form of a T-shaped bar, one end of which is held by a fixed pin while the other is attached to an extensometer, an expansion is often observed during the setting. This expansion increases as the freezing range becomes greater, this result having been confirmed for a number of copper alloys, especially those with zinc.

Subsequent determinations of density show that the alloys have really contracted during freezing, and that the apparent increase of volume is represented by a considerable porosity, distributed throughout the cast bar. The growth of a mass of crystals of dendritic form may, and often does, lead to an outward push, the crystals seeming to repel one another as the liquid between them freezes. The result is that an outer shell is formed, and the contraction of the liquid metal contained in it, as it freezes in its turn, leaves small cavities, which may be so distributed that the casting appears solid unless examined under the microscope.

As another example, the addition of zinc to tin-base bearing metals was found to cause internal porosity, and this was attributed to expansion of the zinc during solidification, followed by contraction of the eutectic enclosed in it. Zinc does not expand and the effect is due to thrust.

Type metals which behave in this way give sharp impressions of the mold, and it was long believed that they, like bismuth and some of its alloys, actually expanded, but determinations of the density prove that this is not so. Antimony, when present to the extent of 10%, reduces the contraction to a very small amount.

As the effect of crystal thrust appears in the outermost shell of crystals, it is chiefly found in the narrow portions of a casting, and becomes negligible where the section is large. For the purposes of the foundryman this apparent expansion is the same as a true expansion in castings of small sections, but it has the effect of making the shrinkage allowance depend on the size. True expansion during solidification is exceptional in alloys.

Notes by the Editor . . .

Discussion Invited—Nay Urged!

EDITORS know only too well that a good article generally represents the viewpoint of the single author, modified though it may be by contacts and experience. He frequently wishes for other viewpoints — in other words for **discussion. Metal Progress** has, since the first, actively solicited letters from foreign metallurgists — and gladly printed others from its readers at home. Informal discussion of this sort has many advantages, the greatest of which is that matters capable of discussion are matters still in flux, and a correct decision is possible only when many facts from many sources are available. Let us have more discussion!

How About Bearings?

THE SUBJECT of bearings would make a good start. This matter certainly has not been stabilized! In the last issue three viewpoints were presented, one American, one British, one German. Those abroad apparently feel that copper-lead bearings are best for the more severe services like crankshaft bearings in gas engines. Two years ago one would say that American engineers agreed, but now the trend is to put them into less exacting service in transmissions and differentials.

Each manufacturer of these bearings containing really high lead has his own ideas, but certain kinds of copper act better than others; also it is difficult if not impossible to re-use the bronze turnings and machine chips. Why?

Closer study of the problems of lubrication and the action of bearings when motion starts or when momentarily dry throws some doubt on the classical view that the proper microstructure of a bearing is a soft matrix containing hard particles. Such a structure can be made in many alloys unsuitable for bearings, and some alloys without relatively hard particles have good antifriction properties. It might be suggested that the soft white metals, tin, lead, cadmium and aluminum, have some undefined essence of oiliness — that is, a great ability to cling to a lubricant and comparatively little power to seize onto steel or iron. What do you think?

Rapid Arc Welding

WORLD RECORDS for arc welding heavy plate have been shattered (as the sports writers say) by the "Union-Melt" process developed by Union Carbide and Carbon Research Laboratories. Metal up to 1 in. and even thicker is joined by one passage of the arc at unbelievable speed. The abutting edges are square or lightly chamfered to a narrow vee and filled heaping full with a powdered material that is an insulator when cold but becomes an electrical conductor as well as a cleansing and protecting slag when melted. Hence an oversize electrode can be inserted into the vee and power simply poured in without heavy short circuits to the abutting steel. The result is an advancing flood of metal, melted from the electrode and the plate edges. Warpage and local hardening are minimized by the speed of travel and the localization of the heat at the focus by the insulating powder.

New Eyes for Science

WE ARE building equipment for looking further out into the infinitely large and further down into the infinitely small. Witness the 200-in. telescope for Mt. Palomar which can see a billion light years, and the new technique for high power metallography which resolves particles a few hundred atoms in diameter. These are extremes too large and too small for comprehension. Yet no new principles are involved; enlarging or refining the older mechanisms to make these marvelous aids to human vision takes fuller advantage of fundamental laws of optics known for a long time.

Vacuum Annealers

FURNACE atmospheres may sometimes be most readily controlled by **excluding** the atmosphere. Steam is a very good substitute when annealing copper and other more inert gases are also used on other occasions. But why not exclude the air by pumping it out of an air-tight furnace?

Such vacuum annealing has been done for some time and in a fairly large way by makers of highest grade transformer sheet of silicon-iron. Furnaces of this sort have also been extremely useful for heat treating magnesium alloy castings. Their utility for heating bright steel machine parts without tarnish is a possibility worthy of study, especially when a slow cooling is desirable. Some objections come to mind: Troubles would doubtless be encountered if the metal had to be withdrawn hot; likewise hot spots might develop in the charge since the action of convection currents would be absent and heat transfer occur only by radiation from hot element to cold metal and conduction throughout the latter.

Controlled Hardening of Tools

I-The Atmosphere

Courtesy Leeds & Northrup Co.

By Fred M. Reiter
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ATMOSPHERE, as related to the heat treatment of steel, means the fluid surrounding the metal at high temperatures. Broadly speaking, these atmospheres could include (1) the true gases — air, products of combustion, ammonia, nitrogen, hydrogen, and many other gases and mixtures thereof, or (2) liquids — such as various salts, lead, cyanide, or (3) even solids — charcoal, carburizing compounds, inert cuttings — although gases exist and are formed in the interstices of these solids.

In this discussion, since we are examining a special furnace for tool hardening, we are interested generally in carbonaceous gases, and raw natural gas in particular, since this muffle batch furnace contains a flow of natural gas unmixed with air or other gases — or, as we shall call it, "raw gas."

Published literature on the many gaseous atmospheres used in industry for all kinds of heat treating operations on various metals has been voluminous, and confusing if not conflicting. When you leave the library and go into the plant you find that each plant or manufacturer has a special "atmosphere" supposed to be the best.

In the furnace mentioned we have found raw natural gas a very satisfactory atmosphere almost perfectly controlling the surface conditions of steel tools and dies. We said "almost," since we seem to approach perfection by half the distance at each step and of course never get entirely there.

In the general run of tool hardening we aim to keep the surface of the steel unchanged chemically; that is to say, in the same condition after heat treatment as prior to heating. This implies a condition of perfect equilibrium between the elements of the steel and the constituents of the atmosphere, and this condition involves three principal factors:

1. The composition of the atmosphere.
2. The composition of the steel.
3. The temperature.

Other factors, such as quenching, handling, design, while important in tool hardening, do

not affect the surface conditions in the sense above stated. *Time* is a vital item, since by prolonged exposure, improper conditions are aggravated. Under perfect equilibrium conditions, time ceases to have any effect; and if perfect equilibrium could be achieved, leaving the tools in the furnaces for long periods should not affect their surfaces.

We can readily see that variations in any of the three factors bring about a great many combinations of circumstances that have limited the procurement of good results for a wide variety of work from any one furnace, whether the atmosphere is a curtain of gas or is a liquid bath, whether the muffle is fed externally generated gases and these dehydrated, chilled, or chemically treated. Our ability to modify furnace conditions under exact control is very imperfect, unless we pack tools in boxes of purely inert substances, or confine our operations to a single equilibrium condition.

Scaling

Scaling or oxidation of the surface of the steel is an undesirable phenomenon, the effects of which we all recognize. A great deal of work has been done and published on the chemical reactions involved and the resulting benefits have been prodigious.

Simply (and inaccurately) scale is formed thus:

$$Fe + O \rightarrow FeO$$
$$2\,FeO + O \rightarrow Fe_2O_3$$
$$3\,FeO + O \rightarrow Fe_3O_4$$
$$Fe_3O_4 + Fe \rightarrow 4\,FeO$$

and the cycle continues, digging into the metal, sloughing off tons of iron every year. While the scaling reactions do not follow exactly the routing given above, it serves to illustrate the effect of oxygen whether this oxygen comes from the air or some gaseous oxides, thus:

$$Fe + H_2O \rightarrow FeO + H_2$$
$$Fe + CO_2 \rightarrow FeO + CO$$

We do believe that oxygen, O_2, water vapor, H_2O, and carbon dioxide, CO_2, are the public enemies in this racket and if we can rub them out, we save the steel.

With mixed gases we have the eternal triangle to deal with:

Oxidizing Gas ← Reducing Gas
Iron

We send in reducing gases to act as G-men to rout the oxidizing gases. In other words, as well presented by Jominy, Wood and Murphy, if we maintain enough hydrogen (a reducer) in ratio to the water vapor present in the atmosphere, and also enough carbon monoxide (also a reducer) in relation to the carbon dioxide, scaling can be prevented. Unfortunately, as most everyone knows, these ratios for equilibrium are different for each temperature and steel.

Decarburization

The use of raw natural gas eliminates the problem of scaling very simply because it is very dry, practically devoid of free oxygen and carbon dioxide, and quite rich in methane, CH_4, and hydrogen derived from methane, two thoroughly reducing gases.

A greater problem by far, especially for high carbon toolsteels, is the loss of carbon from the surface. The higher the carbon content, the more freely does the carbon vanish, resulting in soft skin, poor tools, lowered fatigue life, and distress to all concerned.

Oxidizing agents attack carbon even more readily than iron, and from ambushes as well! Thus:

$$C + O_2 \rightarrow CO_2$$
$$C + CO_2 \rightarrow 2\,CO$$
$$C + H_2O \rightarrow CO + H_2$$

Other footpads are accused of helping in the larceny, including H_2, NO_2, SO_2, although I believe they are on probation.

The assault is quite determined and hard to repel. When highly reducing atmospheres fail, especially on the very high carbon steels such as high carbon, high chromium, the tools are either tucked into packed boxes, dunked into salt baths with a pinch of cyanide seasoning, or other more or less drastic means used.

In this matter of decarburization equilibrium must again be maintained although with much greater difficulty. The ratios of oxidizing

DAYTON CHAPTER, last spring, held a "Panel Discussion on Controlled Tool Hardening" that lasted far, far into the night. It was limited to one particular furnace as operated by one of the Dayton members, locally famous for its excellent work. It brought out some very practical views on some very abstruse physico-chemical problems—and for that very reason is worthy of reporting in METAL PROGRESS.

to reducing gases that defeat scaling are not great enough to keep the carbon in the steel, and the variables much more numerous. The line of demarcation between decarburization and recarburization is exceedingly narrow and we can go from one to the other just like falling off a log — to either side! In scaling we have but one side of the line to work on, but in some tools carburizing may be less desirable than decarburizing.

Again, with raw natural gas for our atmosphere the problem becomes greatly simplified, but still is tough enough. We know that we can carburize quite readily with natural gas. We can, strange to say, also obtain a decarburized surface. To do neither all we need to do is find the point of equilibrium between:

1. The "vapor pressure" of the carbon in the steel, meaning the tendency of the carbon to leave the surface.

2. The "vapor tension" of the carbon in the atmosphere, which is related to the presence of nascent carbon.

3. The temperature, which determines these "vapor properties" of both the given steel and the atmosphere.

This needs some explaining. First, it is my belief — and that of others too — that all these carburizing reactions take place between free atoms and that the elements involved can only be in this state for an instant when released from a cracking molecule. Thus the decarburization of cementite by means of carbon dioxide can only take place if a molecule of CO_2 happens to crack up next to a particle of iron carbide that had just released an atom of carbon to put it in a free or nascent condition. The reaction may therefore be written thus:

$$\begin{aligned} Fe_3C &\rightarrow 3Fe + C \\ CO_2 &\rightarrow CO + O \end{aligned}$$

and the result is 3 Fe (decarburized iron) and two molecules of carbon monoxide.

In other words, decarburization is a gamble depending upon the chance meeting of the authorized molecules of cementite and decarburizing gas which thereupon produce the nascent atoms in close contact and they then perform the reaction. The more cementite molecules (higher carbon steel) and the more oxidizing gases present, the greater the probabilities of such a meeting of these atoms and the greater the decarburization at the surface (temperature remaining the same).

The remedy would be to have no decarburizing agents present or to supply sufficient nascent carbon atoms to overwhelm the exodus of the carbon from the cementite. Raw natural gas fits the bill in its dearth of oxide gases and its copious supply of hydrocarbons that crack readily to yield nascent carbon atoms. The higher the temperature the greater the percentage of cracked methane or gas molecules (the ability to carburize increases rapidly with the temperature). Of course, these molecules of methane and other hydrocarbons must crack up at the exact point on the surface of the steel where it is needed and in the amount required. Many molecules miss the target and produce what soot is found on the work.

Let us emphasize again that if we could establish and maintain equilibrium between steel, atmosphere and temperature we would not have to worry about time or the circulation of the gases. However, exact equilibrium is commercially impossible to achieve, nor is it commercially possible to exclude all oxygen or oxygen-bearing gases or compounds from the furnace. The solution of this dilemma has been found in the furnace operation we are now discussing, and that involves a constant flow of fresh gaseous atmosphere past the hot steel, to sweep out any active oxygen-carrying gas that may be carried in, or seep into the furnace or be exuded from the steel or the furnace lining, or appear as the result of reactions at the surface of the steel. Gas circulation merely has the effect of bathing the hot steel constantly in a gas of fixed composition; in other words maintaining constant item (2) above (atmosphere).

The problem then resolves itself in the control of the flow of raw natural gas past the steel tool — since the carbon content of the steel and the temperature are fixed by specification. The higher the temperature the lower the rate of flow of gas necessary to hold the carbon and to avoid carburization, since more nascent carbon atoms are available (the atmosphere has a higher "vapor tension" of carbon). The higher the carbon content of the steel, the higher is its carbon "vapor pressure," and more carbon atoms must be provided in the atmosphere to establish equilibrium between the two materials in contact. By means of proper flow gages on the gas line to the muffle, and evaluation of the flame jet of the exit gases, calibrations can be made and operations repeated. Each type of steel with its temperature of hardening obtains its predetermined rate of gas flow.

Part II—The Steel

By L. H. Grenell
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WHILE the previous paper has discussed the various reactions of iron with those common gases that cause scaling or decarburization of steel, no consideration has been given to the effect of the composition of the steel being treated on the furnace atmosphere necessary to produce the desired results. Elimination of scale in heat treatment is relatively easy by the use of atmospheres produced by partial combustion of many types of fuel, but nearly all such atmospheres cause decarburization, which results in fatigue failures and a soft skin on hardened parts. As a result, most furnace atmospheres are adjusted to produce a minimum amount of scaling and still avoid decarburization, since an atmosphere which forms the proper scale will usually prevent decarburization. In other words, a compromise atmosphere is used which must be adjusted for each type of steel treated.

Appearances Are Deceiving! Tool at left scaled uniformly 0.005 but was hard underneath. Tool at right had 0.010 in. of soft skin

An improvement in this situation would require a better understanding of the causes of decarburization, and in the following the writer has assembled some data from the literature relative to the effect of various compositions of the steel on its decarburization by hot gases.

Gases Producing Decarburization

In order to determine susceptibility to decarburization, a knowledge of the gases producing this effect is necessary. In Engineering Research Bulletin No. 18 of the University of Michigan, W. E. Jominy reports a study of the relative power of various gases to remove carbon from various steels. Arranged in the approximate order of decreasing power to produce decarburization, the following gives the results of tests on simple atmospheres, that is, of essentially one gas.

1. Wet hydrogen gas was found to be the most strongly decarburizing, producing a noticeable effect at 1000° F. for 24 hr. As this gas is present in nearly all prepared gases that have not been dried, it probably accounts for a large part of the decarburizing effect of these gases. However, adjustment of the ratio of hydrogen to water vapor effectively reduces its effect.

2. Carbon dioxide is the next most active decarburizer, causing decarburization at temperatures as low as 1350° F. This gas is also present in prepared gases and its action may be controlled by proper adjustment of the carbon monoxide to dioxide ratio.

3. Steam was found to cause perceptible decarburization after 5 hr. at 1450° F., while air showed very little decarburization after 5 hr. at the same temperature. Jominy points out that scale formation seems to prevent decarburization; this probably accounts for the results reported for air.

4. Pure, dry hydrogen did not decarburize after one hour's heating at 1600° F., and very little after one hour at 1700° F. As little as 0.1% moisture, however, produced decided decarburization at 1350° F.

5. Pure, dry nitrogen did not produce decarburization, but moisture or oxygen in amounts as low as 0.1 to 0.3% in nitrogen causes decarburization.

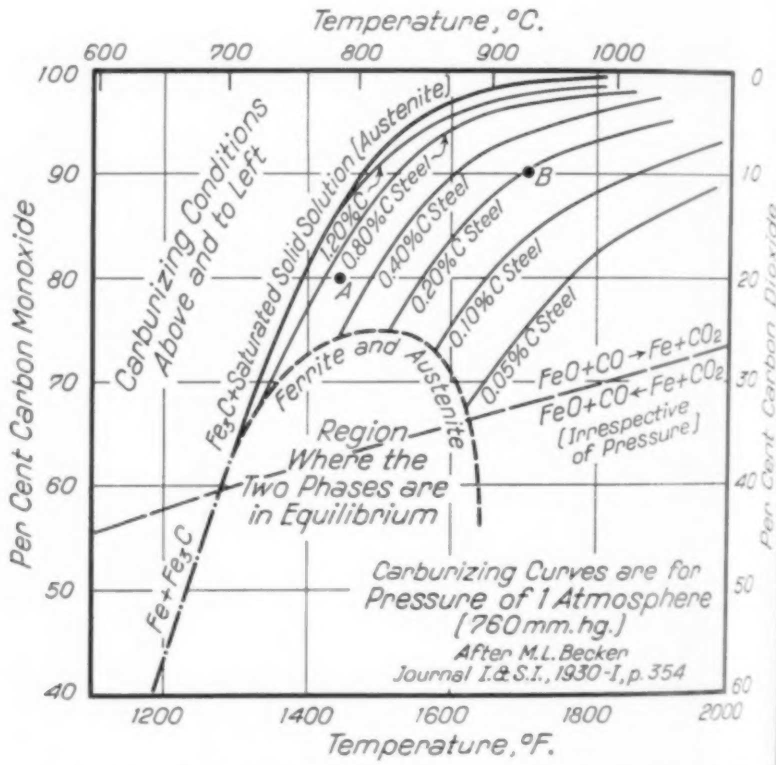
The unsatisfactory results caused by the presence of moisture in atmospheres for bright annealing or heat treating is pointed out by A. G. Hotchkiss in the April 1937 issue of METAL PROGRESS, and a method for determining the amount present is mentioned.

The above gases include those which are most likely to cause decarburization or scaling and are all found in pre-formed gases used for heat treating and in open gas furnaces where products of combustion form the atmosphere. The desirability of removing moisture is readily apparent from this investigation and is a factor which has received little attention in the design of some furnaces for heat treating in controlled atmospheres. The usual method relied upon to overcome this condition is to use atmospheres in which the ratios of hydrogen to water vapor and carbon dioxide to carbon monoxide are such as to avoid decarburization at the temperature used, with the alternative of using a sufficiently oxidizing atmosphere to form a minimum of scale and thus prevent decarburization. However, this latter method results in some dimensional change.

Carbon Content of Steel — The equilibrium of steels of various carbon contents with carbon monoxide and carbon dioxide has been investigated by M. L. Becker and reported in the *Journal* of the Iron and Steel Institute, Vol. 121, 1930, Part 1, page 337. His principal diagram is reproduced herewith, which shows that for an atmosphere containing only carbon monoxide, CO, and carbon dioxide, CO_2, the permissible amount of CO_2 to prevent decarburization and carburization varies with temperature and carbon in the steel. At 1200° F., 56% CO_2 causes no change in either a 0.10% carbon steel or a 1.50% carbon steel, while at a temperature of 1650° F. only 19.5% CO_2 is permissible for the 0.10% carbon steel and for the 1.50% carbon steel the allowable amount of CO_2 has dropped to 2%.

These data indicate that the composition of the steel has a very definite effect on the composition of the atmosphere which will cause no change of the steel with respect to decarburization. Furthermore, the *temperature* used for heat treatment must be considered to the extent that an atmosphere that gives satisfactory results for a given steel at one temperature may be unsatisfactory for a treatment at a higher temperature necessary for the desired structural changes.

Alloy Content of Steel — Referring again to Jominy's investigation, we find tests made on a number of alloy steels which show the comparative resistance of these steels to decarburization. Tests made in moist hydrogen and carbon dioxide gave results parallel to tests made in typical gas furnace atmospheres containing small amounts of carbon monoxide



***Carburizing Reactions Depend on Carbon in Steel.** Thus: 80% CO, 20% CO_2 at 1450° F.,(point A) will carburize 0.40% C steel and lower, but decarburize 0.80% C steel and higher. However 90% CO, 10% CO_2 at 1700° F.,(point B) is relatively inert to 0.20% C steels, will carburize lower carbon and decarburize higher carbon steels*

together with substantial percentages of carbon dioxide (the amount of water vapor is not stated). Results discussed below were obtained by heating at 1600° F. for one hour. All carburizing grades of steel were carburized to slightly hyper-eutectoid case before testing.

The straight chromium steel S.A.E. 5150 appeared to be most susceptible to decarburization of those tested. The silico-manganese steel S.A.E. 9260 and the plain carbon steel (0.86% C) were slightly more resistant. Contrary to results which had previously been reported,

very little difference was found in the rate of decarburization of plain carbon steels made by different processes. The nickel-chromium steels S.A.E. 3250 and 3115 were somewhat more resistant but not quite as resistant as the 3% nickel steel S.A.E. 2320. The chromium-vanadium steel S.A.E. 6115 gave about the same results as the straight nickel steel, but a tungsten tap steel, containing 0.42% chromium and 1.37% tungsten, showed only about half the depth of decarburization. The 1.50% chromium steel S.A.E. 52100 was little, if any, more resistant than the tungsten tap steel. A cobalt high speed steel containing 12.23% tungsten, 3.92% chromium, 2.11% vanadium, and 3.52% cobalt, showed no decarburization at the temperature of test. With the exception of the S.A.E. 5150 and 9260 steels, all the alloy steels appeared to be more resistant to decarburization than plain carbon steels of similar carbon content.

An interesting effect of atmosphere on 18-4-1 high speed steel was reported by J. P. Gill in his Campbell Memorial Lecture summarized in Metal Progress, November 1936. The inside of samples of high speed steel heated in carbon monoxide did not reach the furnace temperature in 20 min.; when heated in carbon dioxide the furnace temperature was reached in 12 min., while a sample heated in air exceeded the furnace temperature in 5 min. The rapid heating of the samples heated in carbon dioxide and air caused the outside of the samples to be overheated and affected the grain size, and only by adjustment of furnace temperature could samples be heated in carbon dioxide to reproduce the heating curve obtained when heating in carbon monoxide. Furnace atmospheres high in carbon dioxide show effects similar to the tests with substantially pure carbon dioxide.

Summary

The data presented above, while insufficient to provide definite recommendations for specific applications, provide a valuable guide to one desiring to use atmospheres for heat treating. S. K. Oliver of the Dayton Chapter presented a paper at a Tri-Chapter meeting in April 1935, in which he pointed out the desirability of some experimentation for each application of atmosphere for heat treating due to variations in the composition of the gas supply. Knowledge of the moisture content of the prepared gas is of considerable importance in securing uniformly satisfactory results.

III — The Results

By E. C. Adkins

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When considering results of heat treatment in various atmospheres, it is proper, I suppose, to refer first to the older type of open-fired gas furnace which is still used rather extensively. The atmospheres in this type of furnace are naturally the products of combustion, the result of a mixture of fuel gas and air, and are dependent upon the operator's opinion as to what constitutes an oxidizing or reducing atmosphere. I have failed to find any so-called reducing atmosphere in this type of furnace; neither have I found a non-oxidizing one that was not decarburizing. Usually an extra effort toward a reducing atmosphere will increase decarburization and scaling when reduced pressure in the chamber allows air to infiltrate from the outside.

Until a few years ago, most authorities recommended a "reducing atmosphere" to prevent decarburization. The general opinion now seems to favor the opposite — an oxidizing atmosphere which forms a protective scale, thus preventing decarburization underneath. This latter opinion has been upheld in my experience except in the case of high carbon, high chromium steel and a few others. It is generally known that high carbon, high chromium toolsteel does not scale readily, and decarburization therefore may take place before a coating of scale is formed. Another steel containing 1.25% carbon and 3.5% tungsten scales readily enough but decarburizes readily in spite of the scale. Most eutectoid steels, whether straight carbon or alloyed, perform similarly to the tungsten-carbon steel just mentioned.

The greatest difficulty is experienced when attempting to heat rather large pieces with cross-sections of 6 in. or more without decarburization, pits, or soft spots. It is then that the hardener would give his kingdom and fifty hours of his time, not for a horse, but for an atmosphere to heat this piece thoroughly to the proper temperature without suffering surface defects. We usually obtain fair results in a "reducing atmosphere" with sufficient pressure to prevent entrance of outside air.

So much for the open furnace, gas fired. Now consider an electric furnace without atmosphere control. My experience with this type of furnace for the hardening of tools has not been particularly satisfactory. The atmosphere is whatever God sends and is usually bad — often worse. Atmosphere control is absolutely necessary in either gas or electric furnaces.

Prepared atmospheres in these furnaces are usually the product of partial or complete combustion of fuel gas, or gas-air mixtures based principally on $CO:CO_2$ ratios. Allowing for certain exceptions, I have found such an atmosphere to have few advantages over those obtained in the open-fired gas furnace, other than as a better, simpler means of regulating and controlling the atmosphere. In other words, my experience is that with most steels the best results are obtained from an atmosphere comparable to that of the open-fired gas furnace, or one containing some free O_2 and little or no CO. There are, of course, some exceptions such as the above-mentioned high carbon, high chromium steel, which may be heated in an atmosphere containing considerable carbon monoxide with fairly good results. Even then there is formed a thin coating of oxide which so strongly adheres to the steel that it can be removed only by pickling or grinding. High speed steels behave in much the same way in this atmosphere, although they form a little heavier coating of scale which will flake off almost completely during the quench.

Similar results may also be obtained with high speed toolsteel in an open-fired gas furnace by adding raw gas to the combustion gases and controlling the pressure or velocity of the combustion gases. Or it might be possible to obtain such results from the combustible gases alone by cutting down the air at the burner, if it were possible to maintain the temperature required with such partial combustion as is necessary to produce the desired atmosphere.

Must Eliminate the Oxygen

From my own experience, I am convinced that it is impossible to heat steel in any of these atmospheres without getting either scale or decarburization. I believe that so long as there is oxygen present in any form or combination, we will get scale or decarburization unless there is present another element which will overcome its deleterious effects. Even then, only a small amount of oxygen can be tolerated.

The atmosphere we are seeking is one in which steel may be heated indefinitely without any oxidation or change in composition unless we so desire. Until such atmospheres are obtained, heat treating will remain a hit-and-miss process, the results of which will remain more or less unpredictable.

It is my belief that the solution to this problem lies in the use of a raw hydrocarbon gas, such as the natural gas obtainable in Ohio. We all know it to be a simple matter to carburize a low carbon steel with this gas and when I speak of an atmosphere of raw gas, it will be assumed by many that we will have a carburizing condition for *any* type of steel. However, I have found that a high carbon steel can be *decarburized* as well as carburized in an atmosphere of this raw gas at any temperature between 1300° and 1900° F. During the past two years, the same has been found true of many different steels, such as high carbon, high chromium, straight carbon and alloyed toolsteels, and even medium carbon alloys such as S.A.E. 3145, 6150 and 5150. With proper control, on the other hand, we have treated all the above steels with no scale or decarburization whatever.

I do not mean to imply that the passing of one definite amount of raw gas through the chamber will give the same results on all types of steel. An atmosphere may be neutral to one type, decarburizing to another, and carburizing to still another. For instance, an atmosphere that is neutral to a 1.00% straight carbon steel may be carburizing to S.A.E. 5150 and decarburizing to a 1.00% carbon steel alloyed with tungsten. With proper regulation and control of natural gas, I can state that a neutral, a carburizing, and a decarburizing atmosphere may be produced for almost any type of steel. In originally determining standards of procedure for establishing any desired atmosphere, we must first start at either the carburizing or decarburizing point and work toward the objective by trial stages. Having once gained these data, it is a simple matter to duplicate the required conditions and obtain identical results.

Among the obvious advantages which have resulted from the use of this atmosphere are freedom from scale and subsequent loss in size; eliminating pack hardening of steels that formerly could be hardened in no other way; heating thoroughly without deterioration; greatly decreasing cracking during the quench; reducing the distortion (due to the ability to quench from a falling temperature).

Surface Hardening with the Oxy-Acetylene Flame

By A. K. Seemann

Engineer

The Linde Air Products Co.

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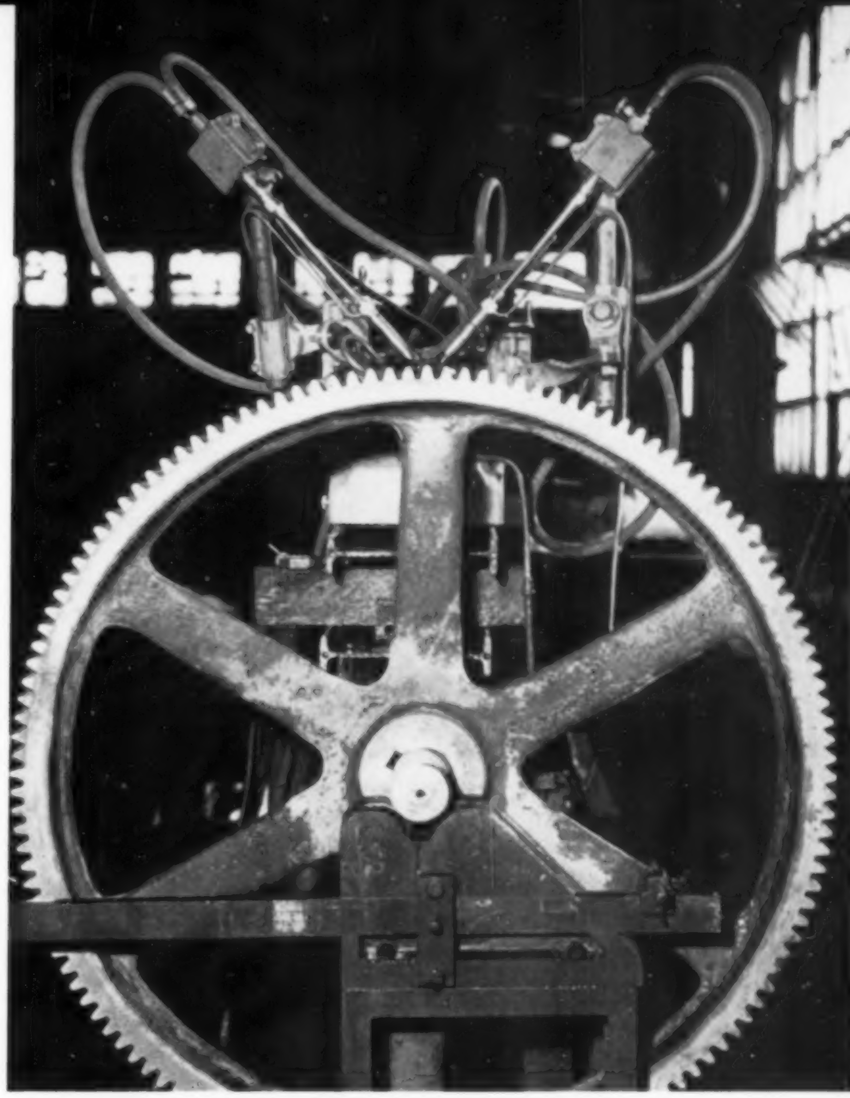


Two Heating Blowpipes, Each With Multiple Flames, Slowly Traverse One Tooth After Another. Water nozzles are attached to each blowpipe so the hot metal may be quenched promptly

DURING the past decade a considerable amount of research has been devoted to an investigation of the commercial and metallurgical phases of what is now quite commonly known as the "flame hardening process." While the basic concept of the process is a simple one, it has been found necessary to study the metallurgy rather carefully and, of course, develop the necessary oxy-acetylene apparatus to apply the process commercially.

Because some confusion already exists relative to what is meant by flame hardening, it seems appropriate to define it as a process wherein the surface of a ferrous material, capable of hardening by quenching, is locally hardened through the agency of an oxy-acetylene flame, followed by a suitable quench. The process does not alter the chemical composition of the metal and, therefore, should not be confused with case hardening, nitriding, Chapmanizing, cyaniding and other processes in which the surface composition is changed to hardenable alloys.

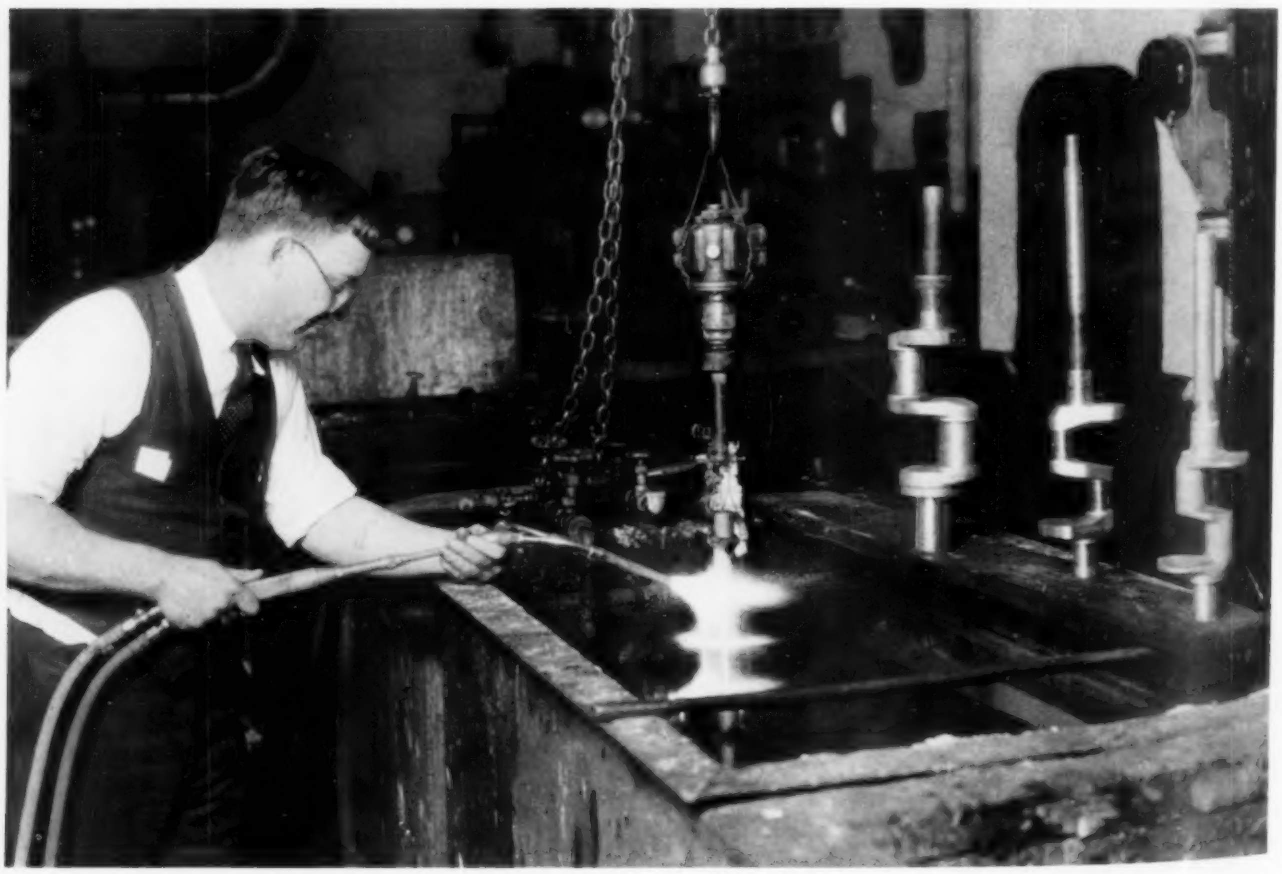
Advantages of the Process — The essence of flame hardening involves the production of a temperature gradient in the steel, whereby the surface portion to be hardened is raised to a temperature above the allotropic transformation temperature while the remainder of the steel body is to all intents and purposes unheated. This not only makes it very much easier to quench the surface zone to be hardened (because it is not necessary to abstract a large amount of heat from the center) but likewise is of real benefit with respect to the ductility of the hardened zone so produced. In usual hardening methods case and core both undergo allotropic transformations (phase change) and the accompanying volume change in the core produces a marked increase in the magnitude of the internal stresses in the hardened case. By eliminating this deep-seated transformation, these internal stresses are avoided, with the net result that spalling, chipping and similar difficulties common to very hard cases are reduced markedly. Experience has shown this to be of

major industrial advantage, and relatively ductile though hard surfaces have been produced on articles of such size and shape as to make the production of satisfactory cases by other methods impractical.

The process therefore has many applications although it is by no means a universal method of local hardening applicable to all types of such heat treating. It has outstanding advantages such as the hardening of wearing surfaces on large machine parts that are difficult, costly, or impossible to heat treat by other methods. Flame hardening is peculiarly suited to applications where a hard surface with a tough, ductile core or body is desired.

There are applications where some machine part, because of desired physical properties, must be of an alloy steel unsuited to case carburizing. The flame hardening process provides an excellent method of obtaining the desired hard surface without changing the properties of the core. Highly specialized methods of heat treating with specially designed furnaces have been developed for differential hardening of many parts. While these have been and will continue to be very successfully used, there are many places where flame hardening can replace them. The speed of heating in these special furnaces is slow as compared with the oxy-acetylene blowpipe with the result that the heat, and consequently the hardness, penetrate to too great a depth. This often sacrifices the surface hardness in order that the body or core of the piece will retain the desired properties. These more conventional methods of differential hardening must avoid thin sections, say ½ in. thick, because the slow speed of heat input raises the entire section to the hardening temperature. On the other hand, the speed of heating by the oxy-acetylene flame is so fast that sections as thin as ⅜ in. and even thinner may be surface hardened with proper technique.

The hardness obtainable by the flame hardening process is at least equal to that obtainable on steel of the same analysis after furnace heating and then quenching. In fact, on heavier sections the unheated underlying metal will assist the external quenching medium and per-



The Shoulder of These S.A.E. 1045 Crankshafts Must Be 80 Scleroscope Hard, to Wear Against a Bronze Seal so the Shaft Is Spun in Front of a Localized Heating Flame, Then Dropped Into the Quench. Photo courtesy Norman E. Woldman

mit the use of a less drastic quench than would otherwise be required.

Because the part is briefly raised above the critical point and then promptly quenched, flame hardened parts are scale free. Generally speaking, distortion is well within manufacturing tolerances. Obviously, as distortion is a function of thickness of material and depth of hardening, great care must be exercised in hardening thin sections because such sections are likely to be heated throughout. Thick sections present no problem because the core is but slightly heated.

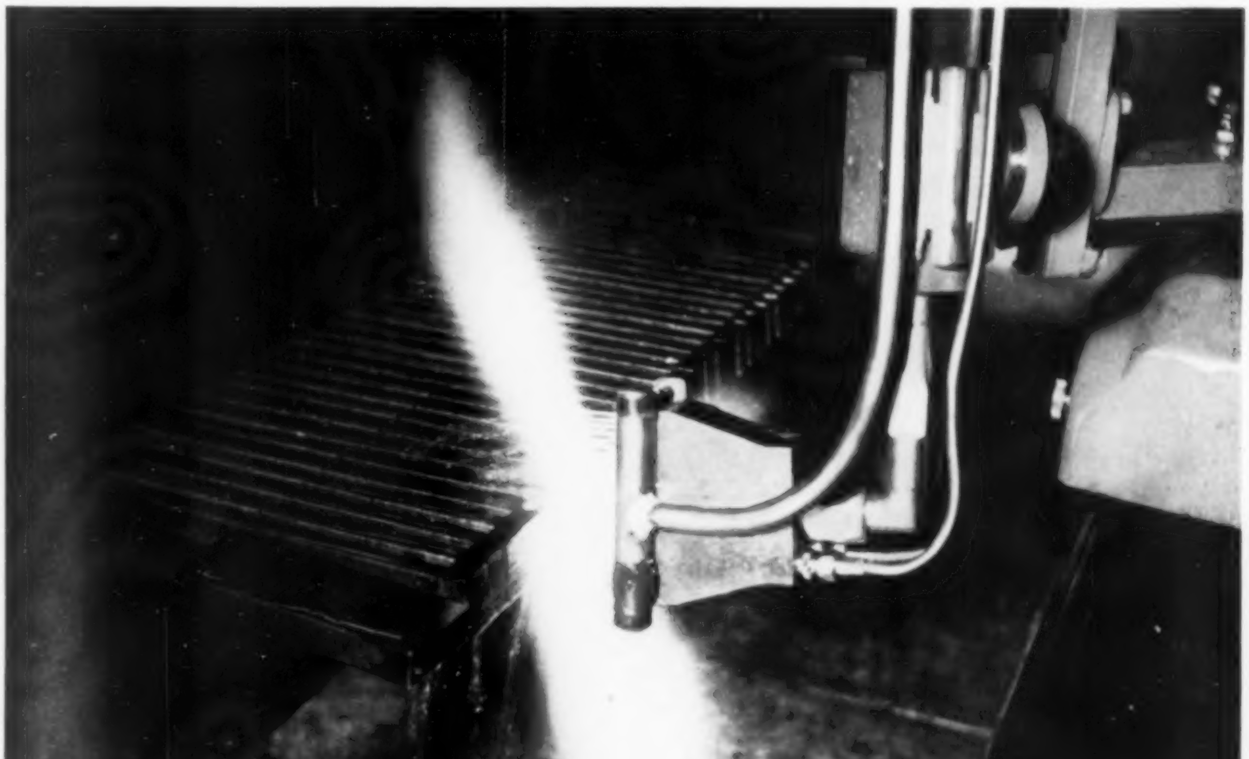
The hardened depth may be varied within reasonable limits. It is a function of heat input and traversing speed, and because both factors are under complete control, case depth is uniform. Ordinary requirements call for from $\frac{1}{16}$ to $\frac{1}{4}$ in. of hardened metal at the surface.

A correct conception of flame hardening implies a process having high adaptability as to the size, shape, and composition of the metal part under heat treatment. This has been borne out in practice and is illustrated by the commercial hardening of such varied articles as rail ends, pump liners, crane wheels, gears, tractor shoes, sheave wheels, machine ways, valves, crankshafts, camshafts, and many other parts.

The process also suggests portability and this is a fact because the apparatus requirements are comparatively simple and light in weight. The tool can be, and often is, brought to the work. It is a great contrast with a bulky mass of brickwork comprising a modern furnace.

This process permits greater freedom in the selection and treating of desirable steels which, when furnace hardened, are prone to check or crack. This is true because only a comparatively thin layer of metal is raised above the critical point, cooling is both external and internal, and the effect of dilatation is consequently reduced.

Steels — In general, any steel which may be hardened by simple heating and quenching may be treated by the oxy-acetylene flame. In addition, cast iron and alloy cast iron may be flame hardened. The list of ferrous materials susceptible to flame hardening is an imposing one. It includes practically all the S.A.E. steels with more than about 0.35% carbon, and some others like carbon-vanadium, cromansil, and graphitic steel. In order to obtain a maximum degree of hardness the carbon content should be at least



A 30-Flame Heating Head Is Attached to a Modern Cutting Machine, on the Bed of Which Are Nested 50 Jaws for Pipe Wrenches. The surplus gas nozzles are plugged, the flame traverses the surface to be hardened, and the heated metal is immediately quenched in a water spray

0.40%. Steels containing more than 0.70% carbon require greater care to prevent surface checking or cracking. The most desirable steels are the low alloy steels, but certain of the high alloy varieties may be sufficiently hardened without a water quench.

The alloy steels have the additional advantage that they resist tempering to a much greater extent than plain carbon steels. Such tempering occurs to a minor degree (in steels which have had a preliminary heat treatment) in the zone immediately below that which has been hardened. This may be of engineering importance where high fatigue stresses are involved.

In general, fine-grained steels are preferable to coarse-grained steels, yet the shallow hardening characteristics of fine-grained steels are not a disadvantage because of the relatively thin layer to be hardened. Steels of the S.A.E. 6100 series (chromium-vanadium) have proved to be particularly adapted to flame hardening because of the grain refining influence of vanadium.

Methods — It is convenient to divide the application of the flame hardening process into four methods. They may be referred to as (1) stationary, (2) progressive, (3) spinning and (4) combination.

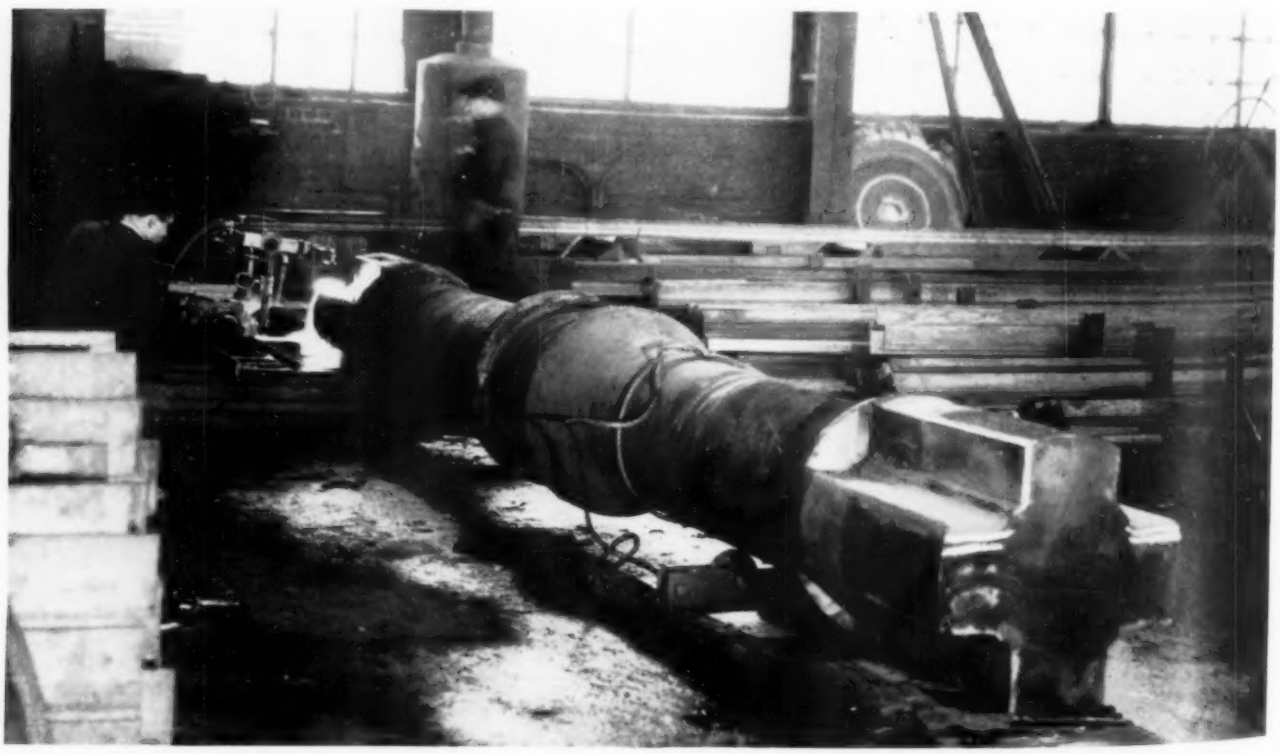
The *stationary method* refers to those operations where the blowpipe and work are motionless during the treatment. This is sometimes known as spot hardening.

The *progressive method* refers to those operations where the blowpipe and the work move with respect to each other and the metal is quenched as heated. Illustrative of this method is the flame hardening of flat surfaces such as ways for machine tools.

For flame hardening a plane surface, the lighted blowpipe, with a head producing sufficient flame area to cover the path to be hardened, is directed along the surface at the maximum speed which will heat the surface zone above the critical. Immediately behind the flame is a stream or spray of water which progressively quenches the heated surface. Speed is determined by operating variables such as flame intensity, type of steel being treated, and the temperature desired. It may vary from 4 to 10 in. per min., although the usual speed is between 6 and 8 in. per min.

The blowpipe head should be placed so that the tips of the inner cones are $\frac{1}{16}$ to $\frac{1}{8}$ in. from the surface being hardened.

On circular work of large diameter, the most successful method is that of heating and quenching by one rotation of the part. This type of hardening is a variation of the progressive method except that the blowpipe is held



From Pipe Wrench Jaws (Page 249) to Wobbler Pads on a 9-Ton Spindle Well Illustrates the Convenience and Adaptability of a Modern Cutting Machine Equipped With Flame Hardening Attachments

stationary and the work rotated. A spray of quenching water is directed against the heated surface immediately following the blowpipe.

The *spinning method* is applied to rounds, such as shaft bearing areas. The blowpipe is stationary and the work rotated before the flames. When the entire area has reached a hardening temperature, the quench is supplied while the work is still moving. The speed of rotation is not critical; it is usually about 100 r.p.m. but may vary from 80 to 120 or more.

Typical examples of this sort of operation are the hardening of local areas on shafts (see the view on page 248), and the hardening of small gear pinions having very small teeth.

Where the diameter of the part is greater than 4 in., two or more blowpipes will be necessary — the blowpipes being mounted to heat the same area from opposite sides.

The time required for hardening by this method will vary from a few seconds to 2 or 3 min., depending upon the diameter of the piece treated, the number of blowpipes, depth of hardness desired, and other factors. It is generally undesirable to take more than 3 min. for hardening — any piece that requires more should have more flame, or be treated by the single slow revolution method.

The *combination method* is a combination of the progressive and spinning methods and is applied to rounds where a considerable area is to be treated. The work is rotated before the blowpipe which gradually traverses the piece longitudinally. The flame is immediately followed by a suitable quench. An example of this method is the hardening of the internal area of a cylinder.

Apparatus — From a description of the methods, it is apparent that many articles may be flame hardened by common machines, such as a lathe, if a suitable blowpipe is substituted for the ordinary tool. The major development work has been concerned with the design of oxy-acetylene apparatus of sufficient ruggedness and flexibility to operate under rather severe operating conditions. It is necessary that such apparatus be water cooled and of sufficient gas capacity to treat an area of reasonable size in one operation.

In order to insure uniform heating, a sufficient number of multiple tip heads are necessary in several sizes. In order to accommodate various widths as well as irregular profiles, tips are preferably of the threaded removable type in various lengths. Plugs may be used so that only a portion of a large head may be operated if so desired.

In addition to all-purpose heads, it has been necessary to design heads for specialized applications such as gear tooth hardening, crankshaft hardening and the like.

For progressive hardening it is often convenient to mount the apparatus on one of the standard oxy-acetylene cutting machines. It so happens that the desired speed falls within the range of speeds obtainable with cutting machines and they thus become ideal traversing devices. Except under unusual conditions it is inadvisable to consider manual operation.

Quenching arrangements are easy to set up. In many small operations a stream of water from a round nozzle will cover the area to be hardened. Where a wider path must be quenched, a fan-shaped nozzle or spray may be used. Either of these is easy to make or get.

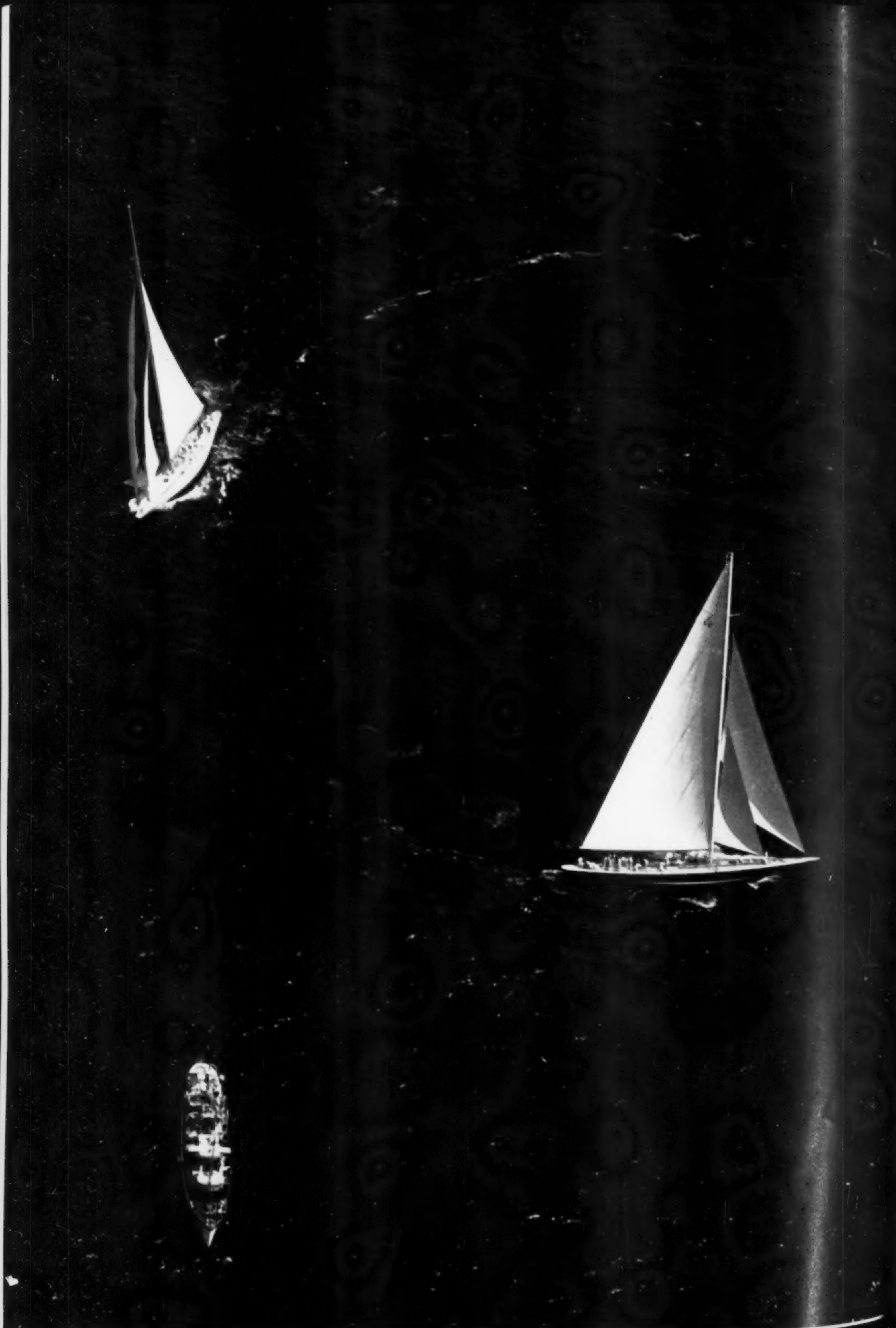
For progressive work, or for the slow revolution method, the pipe carrying the quenching water should be affixed to the blowpipe holder in an adjustable manner so that the operator may direct the stream properly on the hot steel. The quench should follow the last flame closely without interfering with it — this space may vary up to about 1 in.

Better results are usually obtained when the water for cooling the blowpipe and the water for quenching the steel are separately controlled.

For many of the spinning operations on smaller parts, it is advisable to quench with a large volume of water under low head which can be released to cover the entire part instantaneously and flow over it in a continuous stream for the necessary time.

Stress Relieving — Hardening should immediately be followed by a low temperature draw to relieve the quenching stresses. This need not exceed 400° F. and may be conveniently done in an oil bath or oven. This insures against a tendency to surface checking or cracking, and will not reduce the hardness.

Cost of Treatment — It has been found that 4 sq. in. of steel may be hardened with the expenditure of about 1 cu. ft. each of oxygen and acetylene. These figures will serve as a basis for general estimating purposes. Labor is difficult to estimate because it depends to such an extent upon shop facilities, the degree of mechanization of the particular application, and the amount of work going through. In this connection one can estimate that the usual speed of progressive hardening is 6 to 8 in. per min.



Flown
tographed
H. Harris

Metal Yachts Race for the Cup

By John Scott Hughes
The Times; London, England

"AIRPLANE design, the development of high tensile strength corrosion resisting aluminum alloys, and the progress of metallurgy generally, have had a profound effect on the design of modern America's Cup yachts."

It is well for the sailor, when he gasps with wonder at what the scientists are doing for his ancient art, to find an authority who can put the matter so neatly for him. The words are those of W. Starling Burgess, who with Olin Stephens, designed the successful Cup defender Ranger.

The racing yacht of today is more the product of the laboratory than the shipwright's shop. There is art in the job, of course, but art here is the handmaid to science. Formerly the design of a yacht was the work of hand and eye. Whittling a block of wood till it took the shape that he sought — that was how the ship was born. That was how George Steers designed the never-to-be-forgotten America, the schooner that won the Cup in British waters in 1851. That was how Starling Burgess's own father began; that was how most designers of the time worked, including the great Nathanael Herreshoff, who began his successful work on Cup yachts back in 1893.

The change from the whittled model to the drawing board and the calculated curve, however, was not more revolutionary than the adoption of metals, not only for the hull (for that has been a gradual process reaching over many years) but also for the masts and rigging, so that today the whole delicate structure of a racing yacht is a job for the metallurgist, the engineer, and the stress expert.

More progress has been made in the last half-dozen years than in all the time since the British yacht Mosquito was built with an iron hull in the 1850's. This new era of intenser activity began with the American yacht Enterprise, concerning which Metal Progress published an article at the time of her launching, seven years ago. It will be recalled that Enterprise's lavish use of metal included a bronze hull on steel frames, and that, a little later in her career, a mast of riveted duralumin displaced her wooden spars.

In England metals had been much less extensively used up to that time, but when the wonderful Enterprise had taught us such lessons and set the pace we began to get very busy. Endeavour was our answer in 1934, and Endeavour, steel everywhere except for deck and cabin fittings, all admit to be the greatest yacht either country had produced up to that time.

Endeavour II was both a refinement and enlargement of the first Endeavour. Her mast was of high tensile steel from metal specially rolled in Cumberland; stiffened internally by diaphragms, it was a splendid piece of work, and an improvement, some think, on the heavily riveted masts in the American Cup yachts. Another of her improvements on the old Endeavour was the adoption of bar rigging of high tensile steel in place of the wire rope rigging with which the old boat had been fitted in 1934. Endeavour made a plentiful use of a strong bronze for her cleats, bollards and winches.

But again — another example of how the two countries learn from each other and improve on the other's discoveries — though the new Endeavour made some advances on the old, the lessons that the Americans derived from the old Endeavour were so thoroughly embodied with fresh study that Ranger marked an even greater improvement! The testing of tank models was perhaps the most fruitful in results, but her hull structure *(Continued on page 306)*

Nature of the Iron-Manganese Alloys

By Francis M. Walters, Jr.
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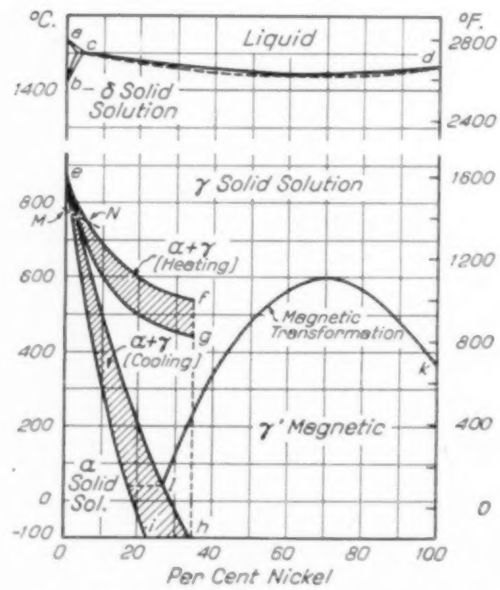
IF A DOZEN metallurgists were asked, "What is the iron-manganese system like?" ten would probably reply, "Why, like iron-nickel." This answer would be only partly right. There are some similarities, but a great many differences.

Both nickel and manganese extend the austenite field and restrict the occurrence of ferrite and delta iron (body-centered cubic); the solidus-liquidus is much the same in both systems — a gradual decrease in temperature from the delta region to the freezing point of the alloying element; there are no compounds in either system; and finally, within certain composition ranges, there are "irreversible" alloys.



Iron-Nickel Constitutional Diagram, According to Merica in Metals Handbook. Only two structural phases exist.

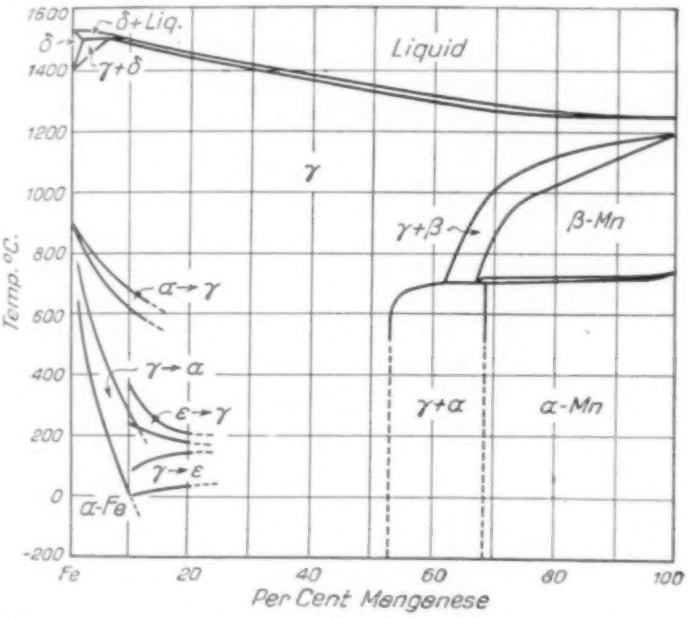
Now let us consider the differences in the two systems: There are only two solid solutions to be found in iron-nickel alloys — *(a)* a body-centered ferrite, and *(b)* a face-centered phase which shows a continuous transition from what may be called austenite to pure nickel. In the iron-manganese diagram, on the other hand, three additional phases are found — *(c)* epsilon, *(d)* alpha manganese, and *(e)* beta manganese. The alloys of iron and nickel are all magnetic; of the alloys of iron and manganese, only those which are wholly or in part ferritic (body-centered cubic in crystal structure) are magnetic.

The manganese alloys show no anomaly of expansion like the invar type (an alloy of iron and 36% nickel). Commercially useful iron-manganese alloys are probably restricted to compositions already in use; such as those containing up to 3 or 4% manganese and alloys in the austenitic range (10 to 16% manganese and high carbon). And finally, nickel and carbon let each other severely alone (at least at rolling and heat treating temperatures) while carbon and manganese are soul mates and much of the unusual behavior of the ternary alloys is easily explained by the assumption that carbon prefers manganese to iron.

Irreversibility — When a 7% manganese alloy is heated it transforms to austenite at 720° C. (1330° F.); when it is cooled from this or a higher temperature it remains austenitic until a temperature of 350° C. (660° F.) is reached. This large difference between the transformation temperatures on heating and cooling is the reason for the term "irreversible." Manganese and nickel do slow up the rate of reaction of iron very much, but with manganese alloys (4 to 13% manganese) and nickel alloys (8 to 30% nickel), the austenite decomposition temperature is lowered sufficiently to stop the diffusion of

nickel or manganese in iron and to "freeze in" the austenite until the temperature is driven low enough by super-cooling to bring about its decomposition mechanically.

Epsilon Phase — When binary alloys containing from 9 to 30% manganese are cooled, part of the austenite transforms at about 170° C. (340° F.) to a modification which has a close packed hexagonal lattice, and is called epsilon. On heating epsilon changes over into austenite at about 200° C. (400° F.). This transformation is reversible. Epsilon is denser than austenite, while ferrite is less dense.



Iron-Manganese Diagram, According to Walters and Wells, Transactions, September 1935. Lines at left indicate ranges where austenite changes to alpha or epsilon phase on cooling, and the higher temperatures where the reverse change takes place on heating. Five structural phases exist

These two methods of the decomposition of austenite are shown in an interesting manner by the dilatometer; when ferrite is formed there is an expansion, when epsilon is formed, there is a contraction. Alloys with 9 to 15% manganese may show both transformations $\gamma \rightleftarrows \alpha$ and $\gamma \rightleftarrows \epsilon$; alloys with more than 15% manganese, show only the epsilon transformation $\gamma \rightleftarrows \epsilon$. The microstructure of the alloys which have only the epsilon $\rightleftarrows$ austenite transformation is a nicely regular Widmannstätten pattern; that of the alloys which contain ferrite may be described as martensitic.

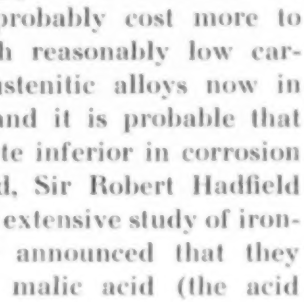
High Manganese Alloys — Manganese has three allotropic modifications. Alpha manganese is a complex cubic with 58 atoms in the unit cell and beta manganese is also a complex cubic, but with only 20 atoms in the unit cell (see the data sheet, page 137 in the August issue). Gamma manganese is face-centered tetragonal, a crystal structure almost like that of austenite. The transformation temperatures are alpha to beta at 740° C. (1360° F.); beta to gamma at 1190° C. (2180° F.). Gamma manganese, the high temperature modification, is ductile, but alpha and beta are quite brittle, as might be expected from their complicated structures. Manganese, purified by distillation, is hard enough to scratch glass, and is fairly resistant to atmospheric corrosion.

Alpha manganese occurs in the binary alloys with as much as 50% iron and since the alpha manganese solid solution retains the brittleness of pure manganese it is unlikely that the high manganese alloys will have any commercial application.

The iron-manganese alloys with 30 to 50% manganese are completely austenitic from their freezing point to absolute zero, but they would probably cost more to manufacture (with reasonably low carbon) than the austenitic alloys now in commercial use, and it is probable that they would be quite inferior in corrosion resistance. Indeed, Sir Robert Hadfield who made the first extensive study of iron-manganese alloys announced that they were resistant to malic acid (the acid found in apples)!

Carbides — According to the X-ray investigations of Westgren and of Öhman the two carbides of manganese are $Mn_{23}C_6$ and Mn_7C_3 which are isomorphous with the chromium carbides of the same composition. No carbide of the composition Mn_3C has been found. These results are in complete agreement with some unpublished work done at the Carnegie Institute of Technology.

These findings contradict flatly the ill founded but generally current expression "Mn_3C is isomorphous with Fe_3C." The truth of the matter (according to Öhman) is that manganese may substitute for iron in masses of cementite up to nearly three atoms of manganese to one atom of iron.



Smooth, Non-Porous Coatings of Tin on Copper

Abstract of articles (and discussion) by
W. D. Jones and Edward J. Daniels
Journal, Institute of Metals, Vol. 58, pages 193 and 199

PRODUCTION of tinned wire from tough-pitch copper is generally carried out satisfactorily, except that the alloy between the tin and the basis copper sometimes is insufficiently intimate and the tin coat adheres to the rubber insulation, thus leaving the copper bare. The correct tinning of sheet copper and copper vessels is more difficult.

When copper is tinned by immersion in molten tin, there are, in general, two types of coating that can be obtained. In the first or "smooth" type, the copper emerges from the tin coated with a layer of molten tin which remains in place as such until it solidifies, forming a coating, which, depending on the conditions of solidification, may either be smooth and bright, or may exhibit typical crystal boundaries or striations. In the second or "irregular" type less tin remains on the copper and may be either accumulated as ridges or isolated globules, the remainder of the surface in each case being very thinly covered. Porosity (a factor intimately connected with corrosion resistance) is from 5 to 20 times as prevalent in the irregular coatings as in the smooth coatings. In the making of copper ware the purchaser is usually more concerned with appearance than with corrosion resistance; consequently many jobs are wiped, the tin layer very thin, and corrosion resistance is very poor.

Pores Caused by Surface Oxide

In a preliminary study of the effect of the quality of the basis metal upon the quality of the tin coating, it was indicated that the production of porous, irregular tin coatings on copper during hot tinning is associated with the presence of inclusions of cuprous oxide in the copper base, and that relatively non-porous, smooth coatings are produced in the absence of such inclusions. There is a simple means of discerning the surface oxides by amalgamating the surface; mercury adheres to the clean copper and converts it to a mirror surface against which spots of oxide (remaining uncovered) are easily seen under a microscope. While it is essential to have a clean copper surface, it is unnecessary to produce a microscopic polish. Amalgamation is best performed by rubbing the copper surface with a soft cloth, wet with a solution of mercuric chloride acidified with hydrochloric acid, then washing and drying.

Therefore the problem of non-porous coatings is, in part, one of reducing the surface particles of cuprous oxide to copper. This can best be done by cathodic treatment under conditions which cause evolution of hydrogen. Specimens were treated cathodically in a solution of 5% caustic soda, with nickel gauze anodes and current densities varying from 10 to 50 amp. per sq. ft. Superficial reduction to copper takes place immediately, and usually a time of treatment of from 5 to 10 min. is sufficient for tinning. Cupric oxide also becomes coated slowly with copper. Doubtless other solutions may be equally satisfactory, but the advantages of caustic soda solution are that it does not deteriorate appreciably, has a high conductivity, is cheap, and does not corrode the nickel anodes. The caustic soda should be washed off before tinning. It is quite possible that the electrolytic degreasing used by electroplaters also involves a cathodic reduction of oxide particles exposed on the surface, since copper articles cleaned in that way "tin" much better than though they were degreased with tri-chlorethylene vapor.

Quite apart from cathodic treatment for the production of hydrogen, it is also possible simultaneously to deposit copper electrolytically by employing copper-bearing electrolytes. Substantial reduction in the amount of porosity can be secured in this manner.

While much of this work was done on copper with an abnormally high content of oxide, artificially produced, the experiments were completely confirmed with ordinary varieties of commercial copper. For instance, oxygen-free copper gives smooth tin coatings of low porosity without any special preparation.

Contamination of Tin Bath

Other work endeavored to discover the degree to which copper contaminates the tin coating and its effect on the nature of the coating obtained. Temperatures and times of immersion were comparable with commercial tinning practice.

Two baths were used, commercially pure tin and tin-lead eutectic solder (62% Sn). Temperatures varied from 500 to 850° F., and time from 5 to 30 sec. In all cases the alloy layer was duplex in all specimens irrespective of the time or temperature of dipping or of the presence or absence of lead. Immediately adjacent to the copper was a band of gray alloy (probably Cu_3Sn), separated from the tin by a white alloy (probably Cu_6Sn_5).

Particles of these compounds break away and

(Continued on page 308)

New Aspects of Fatigue and Creep

Report by John M. Lessells
Associate Professor of Mechanical Engineering
Massachusetts Institute of Technology

Fatigue of Metal Is an Especially Important Consideration in Aircraft, Where Speeds are High and Weight of All Parts Is as Low as Possible

Photograph by Henry M. Mayer

SERVICE conditions to which materials are put by the engineer are becoming progressively more and more severe. Higher speeds and greater powers are being demanded of lighter machines. Factors of safety, so conservative in past decades, are being encroached on to a greater and greater extent. Since breakdowns in high-speed machinery, when they do occur, are unusually destructive, it is important for the engineer to know how far he can decrease these safety factors and still have a safe structure. More precise application of design theory needs more precise test data.

It was therefore proper that a series of lectures on strength of materials at Massachusetts Institute of Technology (June 21 to July 14) should be closed with two well-attended conferences, one on Fatigue of Metals and the other on Creep of Metals. It will be my endeavor to interpret the spirit of the remarks, especially as they represent present trends of experimentation and thought.

Fatigue of Metals

Both fatigue and creep involve the time element, that is *long* time — oft repeated stresses or steady stress month in and month out. Many experimenters are devoting attention to these problems, but that of fatigue attracted attention at an earlier date, and a greater mass of data is therefore available. We in America have largely studied specimens stressed in simple bending. H. J. Gough, in his outstanding contributions to the subject, has studied at the National Physical Laboratory in England all forms of stressing, and he outlined the extensive work now under way on the effects of combined stress. Cooperation in this program is invited, so that the whole field may be systematically explored.

R. L. Templin of Aluminum Co. of America pointed out that designers usually encountered no difficulty in interpreting the so-called static mechanical properties of the light metal alloys.

Greater deflections than in steel under equivalent stresses are easily referred to a great difference in modulus of elasticity — 10,300,000 psi. for a strong aluminum alloy as against 29,500,000 for a steel. It is different with the dynamic properties, since it is usually found that due to lack of understanding of these properties and mal-application of available data the particular design fails to give the type of service intended. This in spite of the wide amount of data on these dynamic properties.

Contrasted with steel where the endurance limit is usually fixed by experiments involving 10 to 20 million cycles of stress, the light metal alloys usually have a life basis of 500 million. Mr. Templin observed, however, that many structures made from light metal alloys are never expected to withstand anywhere near this number of stress cycles.

There is no rough ratio between tensile strength and endurance limit for the aluminum alloys, as there is for the steels. This is shown by a selection of figures taken from Metals Handbook. Their application to such items as locomotive side rods and electrical transmission lines was then described, which emphasized the importance of such items of information to the designer as (1) actual maximum stresses, (2) actual stress distribution, (3) probable number of stress repetitions during the life of the member, and (4) fatigue strength of the metal.

Properties of a Few Important Aluminum Alloys

Alloy	Composition	Tensile Strength	Endurance Limit	Ratio
Castings				
S.A.E. 35	5% Si	9,000	6,500	72
No. 112	8% Cu (+ Fe, Zn)	23,000	8,500	[illegible]
Heat treated	10% Mg	44,000	7,500	17
Wrought Alloys				
52 S-H	2.5% Mg (+ Cr)	41,000	20,500	50
4 S-H	1.0% Mg, 1.25% Mn	42,000	16,000	38
24 RT	4.2% Cu (+ Mg, Mn)	68,000	14,500	21

So the testing engineer's determination is therefore only one of four or more essential items for an intelligent design. This necessary change in attitude toward economical and safe design was emphasized by A. V. Karpov, chairman of the American Society of Civil Engineers' committee on structural design. His remarks were somewhat similar to those presented last fall in a symposium for that Society on Structural Application of Steel and Light Weight Alloys. (See "Modern Stress Theories," *Proceedings*, A.S.C.E., October 1936, p. 1128.) Recent changes in engineering science have profoundly influenced the design of machines, but so far the designer of static structures has avoided the issue by assuming that these new developments were confined to aeronautics, automobiles, and high speed machinery. His conventional designs neglect stress concentrations, fatigue and creep, assume perfectly elastic properties of metals, and presume a mode of load application and jointing which in the majority of cases may not be approached. While such idealized designs may be warranted in simple structures, the trend is now forcing the designer to consider the actual conditions.

R. E. Peterson of Westinghouse Electric & Mfg. Co. dealt with certain phases of the fatigue problem investigated by him, particularly the effects of stress concentration on the type of fracture obtained under fatigue. One of the most interesting features of his presentation was a description of certain service failures and their explanation. Due to the desire on the part of industrial organizations to suppress news of their failures, too few papers of this type are given, which is very regrettable.

The fatigue problem as it affects the railroad industry, with particular attention to helical springs, was the topic of R. W. Clyne of American Steel Foundries. It was indicated that the physical properties of hardened spring steels are materially influenced by the heating operation prior to quenching, by viscosity of the quenching medium, by degree of initial hardness, and by the use of aluminum additions to the steel during manufacture.

By far the most important factor was that of surface conditions. Defects may arise in the surface if the coiling temperature is too high; photographs were shown comparing the good conditions on the surface of springs coiled at 1600° F. with bad conditions arising from temperatures of 2000° F. Surface decarburization was also discussed. This phenomenon is well known and contributes more than any other single factor to the reduction in fatigue strength. Mr. Clyne has already printed an article in Metal Progress in May 1936, bringing forward some of these considerations.

In the light of present known evidence, fatigue has not been a primary cause of aircraft failures, as pointed out by K. Arnstein of the Goodyear-Zeppelin Corp. He did stress the fact, however, that future development calls for a better knowledge of the actual stress variations as these occur throughout the flight history, and suggested the installation of self-recording instruments in craft engaged in regular operation, describing certain of these instruments.

In summary, it may be said that a better understanding of the nature of fatigue as a specific branch of the general problem of fracture in metals is being given us by Gough and his collaborators in England, wherein X-rays are employed (see page 276). The continuation of this work will broaden our ideas on the underlying causes of fatigue. The program of work which is now being carried out on effect of combined stresses (the first phase already having been reported in the technical press) is of great significance in giving the designer a better understanding of how materials behave under stress.

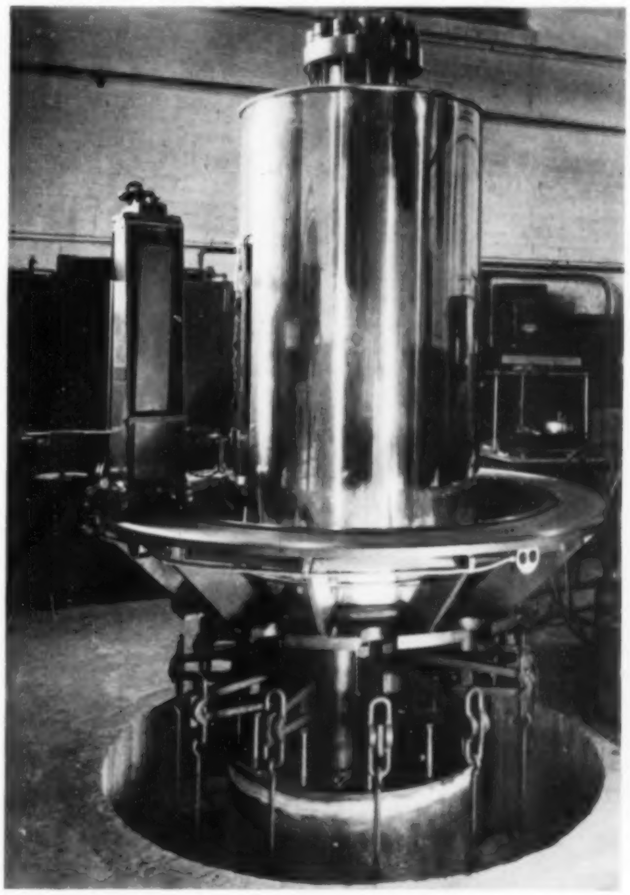
Important contributions are being made by workers in this country. The work of Peterson on size effect and stress concentration, already described in the literature, needs no mention here. The research work by Horger at Timken Steel & Tube Co. on large sized specimens — even full sized locomotive axles — and by H. F. Moore at Urbana on heavy section rails will undoubtedly lead to outstanding contributions to our knowledge. We also see definite steps being taken to incorporate available data in actual design problems by the development of some code of working stresses. In this respect the work of Soderberg and the published data of the Verein deutscher Ingenieure, described by Karpov, are worthy of mention. As more knowledge becomes available, it is expected that a more rational approach to the subject of choice of working stresses will be possible.

Creep of Metals

"Creep" may be simply defined as an increase in elongation of a test piece with time under a constant stress. One manifestation of creep in practice would be the gradual enlargement of the diameter of a superheater tube. "Relaxation" is another phase of plastic flow manifested in the gradual loosening of bolts in flanges on steam lines.

Both are but aspects of the general problem of the use of metals at high temperature, as set forth by H. J. French of International Nickel Co. For this, one must attain satisfactory mechanical properties and retain surface stability. The terms "high temperature" and "low temperature" are relative, since lead at room temperature shows many of the characteristics under sustained stress that steels do at 750° F. to 1000° F. Furthermore, it should be remembered that metals are polycrystalline and their deformation characteristics depend upon intergranular movemment as well as slip within the crystals.

Quite a large part of the talk was devoted to the problem of embrittlement during high temperature service. This was divided into three types: (1) Embrittlement from prolonged heating either with or without applied stress, (2) strain aging which occurs in steel after cold working, (3) embrittlement accompanying recrystallization which follows cold working and subsequent heating to moderately high tem-



Equipment for the Simultaneous Testing of 12 to 60 Pieces, Depending on Length, at Constant Temperature and Tensile Load. Supposedly uniform material has such variable creep characteristics that a mass of good data for statistical analysis is greatly needed

Photograph by Underwood & Underwood

Oil Industry, Especially in the Development of New Processes for Cracking Heavy Petroleum Into Gasoline, Is Asking for Cast Metals to Serve at Temperatures up to 1350°F.

perature. The second and third of these types may be encountered as a result of fabrication such as punching or drilling, while the first may appear in certain steels (relatively free from stress) after they have been subjected to sustained heating and are subsequently cooled. Tests were shown indicating that certain steels tested at normal temperature, after being previously stressed for a long period of time at high temperature, showed a distinct decrease in notched bar impact value. A case in point is the plain 5% chromium steel tubes, mentioned in the article on impact testing in last month's Metal Progress, p. 141.

How creep problems affect the design of steam turbines was shown by A. Nadai and C. R. Soderberg of Westinghouse Electric & Mfg. Co. Dr. Nadai emphasized that the creep problem has been approached by the physicist, electrician, metallurgist, geophysicist, mathematician and engineer, all with their own viewpoints; more progress could be made by a better collaboration between these different scientists. His comparison with the mountain climber having his viewpoint changed as greater altitudes are reached with that of the scientist as greater fields of knowledge are made available was particularly apt to research work in general.

The general problem of the increase in steam pressure and temperature during the last decade was presented by Mr. Soderberg. He pointed out that an increase in temperature from 750° F. to 950° F. represented a difference in fuel consumption of some 18%. At present no operating experience is available for steam temperatures in excess of 825° F., but between 3,000,000 and 4,000,000 kw. of new generators are now under construction designed to operate at 900° F. and above.

The Westinghouse engineers believe that too much effort has been applied to the solution of localized problems, such as a comparison of different materials at the same stress and temperature without inquiring into the behavior of a single reputable material at different stresses and temperatures. The result is that while a considerable quantity of data is already available, much of it is unrelated and one cannot therefore explore the influence of any one of the variables. Another point mentioned was the large variation in results which were obtained from supposedly identical specimens.

New testing equipment (shown on page 259) has recently been built by the Westinghouse Research Laboratories wherein each machine takes 12 specimens of 20-in. gage length, and maintains them constantly at the same temperature. P. G. McVetty presented a full description of this to the American Society for Testing Materials at the July meeting in New York. The relaxation test, a modification of Rohn's plan of automatically lowering the temperature in response to creep in the specimen, has also been used to good advantage. (See C. R. Austin and J. R. Gier's paper in *Proceedings*, American Society for Testing Materials, Vol. 33, p. 293, 1933.) Mr. Soderberg felt that while criticism may be made of the previous testing programs, the results have undoubtedly exerted a real influence on the materials in steam turbines.

The creep test is regarded as the basic source of information with regard to the behavior of such materials. In order to make a mathematical analysis, certain more or less established features of the creep curves are

assumed to be established. These assumptions cannot be rigorously proved but they appear to give reasonable starting points. The problem of relaxation of bolting steels and its possible extrapolation from the creep test was discussed. Finally a review was given of the design of such parts as turbine cylinders, steam piping, turbine rotor and blading.

This general subject was resumed by E. L. Robinson of General Electric Co., who pointed out that the steam turbine requirements for materials at high temperature differ greatly from high temperature service in other industries, allowable deformations being on the order of 1% of the latter, and no bigger than many elastic strains. Misfunctioning in a turbine due to distortion long precedes any strain likely to cause rupture.

Since test results on any particular composition of steel may vary 1,000 to 1 in creep, a large number of *good* test results for statistical analysis rather than a few *precise* ones seem to be necessary to establish a satisfactory control of material. Very small elongations must be measured but this does not save time in the testing program, since progressive strengthening occurs at small strains making extrapolation difficult. Identification from present physical characteristics rather than past history is desirable.

In Mr. Robinson's opinion, relaxation tests have a high metallurgical value as comparative tests because they limit strain hardening. They are also practical bolt tests. But long time, constant stress tests are also necessary.

Types of stress in service involve simple tension at constant stress in buckets and at constant strain in bolts, steady equal principal stresses in rotors, steady stress with 2 to 1 ratio of principal stresses in shells, and bending stresses in diaphragms and nozzles.

The General Electric Co. has run many series of tests wherein the actual change of dimension of parts after years of successful service was measured. In all new equipment working stresses are so chosen as to prevent too early replacements. In this way temperatures have been raised 200° F. in the last ten years with no greater distortions in the turbines, yet with large fuel savings in consequence of the higher operating temperature. Mr. Robinson has reported many of these facts in his article in Metal Progress for September 1935.

The oil refining industry is challenging the valve industry to furnish equipment suitable for service at temperatures up to 1350° F., reported J. J. Kanter of the Crane Co. The problem of designing steel castings for these new extremes of pressure and temperature presents certain metallurgical limitations of alloy steel castings not generally considered by the manufacturers of steel billets and tubes. Attention has been turned to various stabilized modifications of cast austenitic nickel-chromium steel; failure in creep by propagation of cracks through the interdendritic cores of these alloys is a serious problem. The only effective stabilizer in cast 18-8 against brittle failure in creep seems to be silicon, which has the disadvantage of greatly reducing creep resistance.

Studies upon the relaxation of flange bolting materials tend to show that special heat treatment to attain good creep resisting properties is fully as important as the selection of a proper alloy analysis. Alloy steel when normalized generally shows vastly superior creep resistance than when oil hardened and tempered, and the present problem is to develop bolting steels that respond to normalizing heat treatments and still give structures combining adequate strength and elasticity with improved creep resistance. The valve industry must also develop new non-ferrous alloys for pressure applications beyond the present temperature limitation of 550° F.

A. B. Kinzel of Union Carbide and Carbon Corp. pointed out that the creep problems in the oil industry may be divided into two definite categories — first, those met in actual operations, and second, those presented by the research laboratories in their work on new cracking processes. It may be truly said that the problem of creep in itself does not play the major role in their choice of material for actual operations at the present time, because auxiliary properties such as oxidation resistance, corrosion resistance, ductility and weldability are the dominant factors. Moreover, initial cost is an item of great moment in view of the fact that the apparatus in the oil industry is not built to last 20 years, as is the case in the steam power field. Petroleum cracking stills generally are obsolete because of new designs in a very much shorter period. As a result, the materials considered most suitable as far as their technological properties are concerned are generally not employed.

For example, a 25% chromium, 12% nickel steel containing columbium has much greater creep and corrosion resistance than the 5%

chromium steel with columbium which is now being used in new applications in oil cracking stills. The latter steel, however, does have sufficient creep strength and corrosion resistance and is so readily fabricated that it presents the ideal compromise for a unit whose life is to be measured by years rather than decades.

In the case of moving parts, however, the problem is somewhat different. The amount of material is small compared to its final cost in the machine, and pumps and the like which embody the moving parts are expected to have a long life. Accordingly, in these applications high chromium austenitic alloys, stellite, and similar relatively expensive metals are used without hindrance from high initial cost.

In the case of new cracking processes involving higher temperatures and higher pressures than heretofore general, both the creep problem and the corrosion problem present a real challenge to the metallurgist. Here the very best of materials are to be used, and in this case cost is not the limiting factor. As a result, it is necessary for the petroleum engineer and the research metallurgist to cooperate in the design and selection of steel that will meet very special and specific requirements.

In this whole connection it is interesting to note that the use of materials having high creep value has preceded the determination of these values in the laboratory, and once again we have the case of materials giving satisfactory service before quantitative laboratory measurements have been able to predict such service.

Summarizing all the discussion, it appears that in the field of creep there are at least two distinct problems. The first deals with the strictly metallurgical side and is concerned more with giving the engineer materials better able to resist the action of high temperature. This is also concerned with the possible variation which might be expected for different materials, or different lots of what is supposedly the same material. There is, however, another side to the question, represented by the work of Nadai, Soderberg and their collaborators, which is a strictly engineering one and which is concerned with the use of these data in actual design work. Finally, a theory of creep is being rapidly developed based on the wider theory of plasticity, which will eventually pave the way to better understanding of the subject and the conclusion gained from this conference is that considerable progress has already been made along these lines.

Damping Capacity

its practical importance

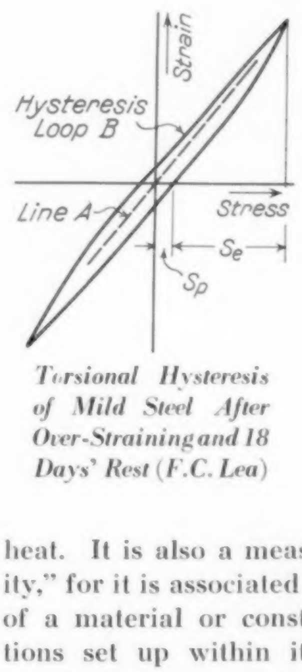
By O. Föppl

Director of the Wöhler Institute
Braunschweig, Germany

Abstract from *Journal*,
British Iron and Steel Institute, 1936, II, p. 393

STRUCTURAL and mechanical designers usually assume that the elastic limit of the material under quiescent, impact or alternating load is nowhere exceeded. According to this assumption a cyclic load would cause the stress-strain relationships to move up and down on line *A* between points within the elastic limits in tension or torsion. This assumption is substantially correct for heat treated steels stressed to but a small fraction of their ultimate strength.

However, a series of precise stress-strain measurements made on bronze or a cold-worked steel will show that below even a moderate maximum stress, the loading and unloading curves do not coincide. A hysteresis loop, such as *B*, is gone through during each stress cycle; a certain amount of plastic distortion is associated with purely elastic movements. In rather rapid cyclic stressing, the work which is measured by the area of loop *B* quickly appears as sensible heat. It is also a measure of "damping capacity," for it is associated with the inherent ability of a material or construction to check vibrations set up within it by external impulses.

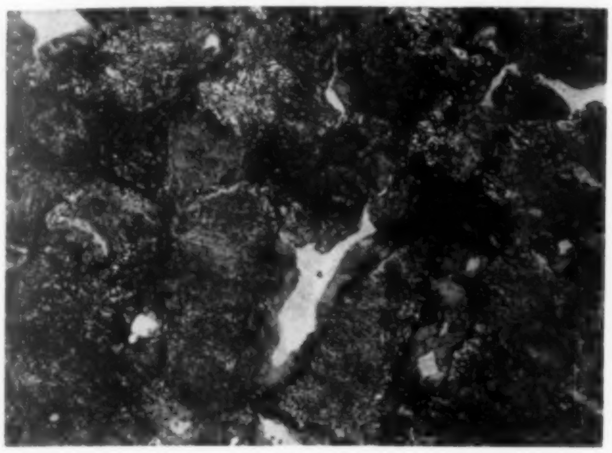


Torsional Hysteresis of Mild Steel After Over-Straining and 18 Days' Rest (F.C. Lea)

A most convenient way to measure damping capacity is to twist one end of a round test piece and then let go. The rate of decay of the subsequent free torsional oscillations measures the damping capacity of the specimen. Damping capacity of hardened ball bearing steel is slight; it vibrates for a long time. Damping capacity for cast iron is great; it ceases vibrating very quickly. *(Continued on page 300)*

Structure of Low Alloy & High Strength Cast Irons

Top four photomicrographs by Research Laboratory, International Nickel Co.
Bottom pair by General Motors Research Laboratory

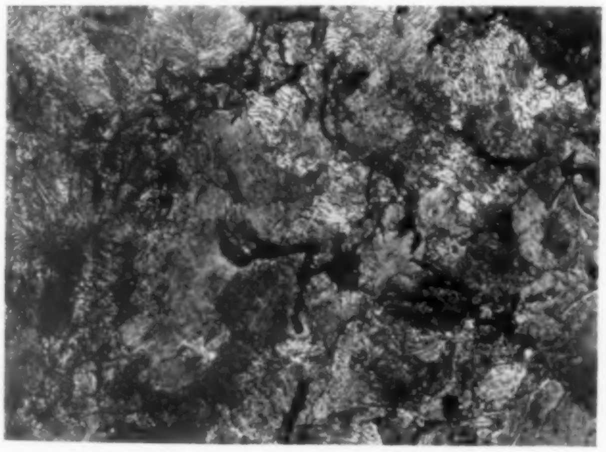


½-In. Section (500X)

2½-In. Section (500X)

Nickel-Chromium Gray Cast Iron (Cylinder Iron)

Total carbon 3.05%, silicon 1.50%, nickel 1.25%, chromium 0.50%. Tensile strength: 35,000 psi.



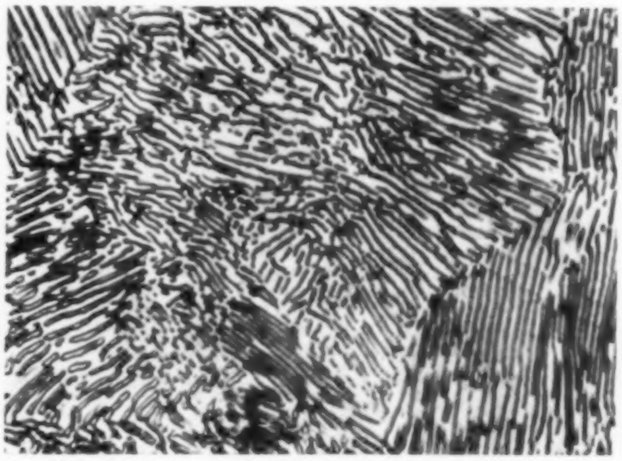
¼-In. Section (500X)

2½-In. Section (500X)

"Ni-Tensyliron," to Meet A.S.T.M. Class 50 (Specification A 48 - 36)

Total carbon 3.0%, silicon 1.75%, nickel 1.0%. Tensile strength: 50,000 psi.

General Structure (100X)



Pearlitic Groundmass (2000X)

High Strength Electric Furnace Iron for Experimental Brake Drums

Melted white; total carbon 2.10%; 2.75% silicon, added in ladle. Tensile strength: 55,000 psi.

ECONOMICAL

...because they pay

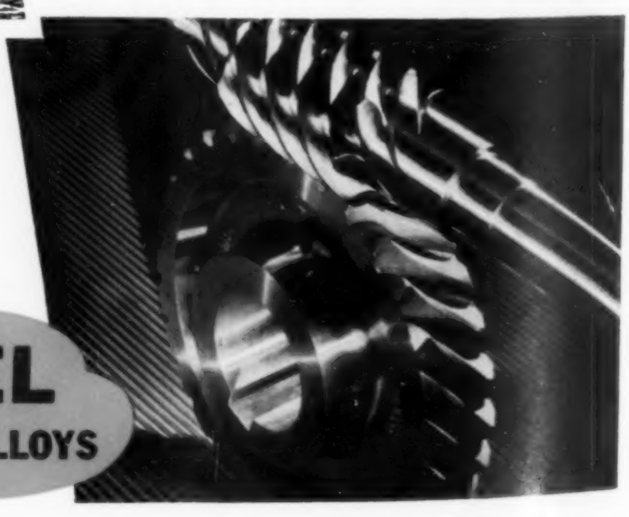
EXTRA DIVIDENDS

in service

A LASTING purchase is thrifty! With solid white bronze—Nickel Silver—fittings, time is turned aside and thrifty buyers reap their reward. Continuous finger traffic, the weather and general wear and tear soon change the appearance of hardware whose beauty is only skin deep. But Nickel Silver resists the rub of fingers and cleaning, the corrosive action of the weather, and the stresses of day to day service. Solid, with no coating to chip or peel, the Nickel Silvers are tough, durable, wear resisting and always beautiful. Their use continually pays dividends in satisfactory lifetime service.

• • •

A STEAM condenser is a unit of thrift to conserve boiler water and make it work again and again. Corrosion, erosion, high pressures and temperatures are the constant enemies of condenser life and maintenance. Therefore, many of the world's leading navies and commercial fleets, shore stations and oil refineries are increasingly using thrifty Cupro-Nickel tubes in their condensers to increase reliability and cut down overhaul and maintenance expenses.



THE best materials are thrifty! This worm gear drive with Nickel-Bronze gear and Nickel Steel worm is an excellent example. Eight of these drives were installed 15 years ago on chewing gum mixing machines demanding steady nine-hour per day service under heavy intermittent load with accompanying stresses. Caution prompted a supply of spares for emergency replacement—but they are still in storage, for after 15 years the original drives continue to prove their real worth and low, final cost. We invite consultation on the use of the alloys of Nickel in your equipment.

NICKEL

NON-FERROUS ALLOYS

THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N.Y.

Note on the

File Scratch Test

By W. C. Hamilton
Research Director
American Steel Foundries
Indiana Harbor, Ind.

"Scratch" and "No Scratch" Method for Finding Surface Hardness by a Series of Sharpened Files

IT IS WELL known that steel may attain a very high degree of hardness on the surface due either to work hardening or to self-hardening. This skin hardness may be only a few thousandths of an inch in depth. When the usual hardness testing equipment of different types is used on such a surface, the thin skin is penetrated and the readings obtained are not at all indicative of the surface hardness.

In other cases it is desirable to obtain the surface hardness on metals when it is not feasible to use regular hardness testing equipment.

A rather crude method for such hardness determinations is a file scratch test, in which specially prepared files are used.

For this file scratch test, it has been found most satisfactory to use square files with tapering sides, 8 in. long. These plain carbon steel files ordinarily have a Rockwell hardness of approximately C-65. By drawing such files at suitable temperatures, the hardness numbers can be reduced to any desired degree:

Draw Temperature	Rockwell Hardness
No draw	C-65
400° F.	60
550	55
660	50
760	46
840	41
960	35
1040	30
1080	25

It should be noted that the files could equally well be calibrated in terms of other hardness values, such as Brinell readings or Vickers hardness numbers.

Files in such a series, drawn to different hardness values, are ground at the file-end to a needle point. This needle point must be maintained by re-grinding when necessary.

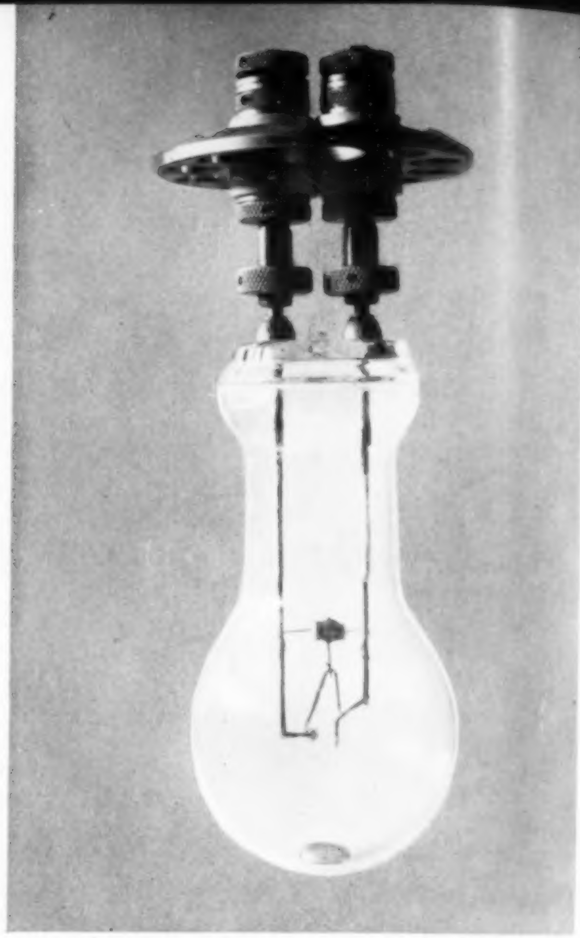
In use it is quite necessary to have a fairly smooth, clean surface on the specimens to be tested.

The test is then made by determining the softest file which will scratch the surface of the specimen. To conserve the points, it is only logical to start the scratch test with the hard files. The precision of the test will naturally depend upon the number of properly tempered files in the series.

An experienced operator can conduct this scratch test through feel: a file that does not scratch, slides over the surface; whereas a file which scratches, grips the surface.

Improved Illumination for Microscopes

By Peter P. Tarasov
Incandescent Lamp Dept., G. E. Co.,
Cleveland Wire Works
Euclid, Ohio



Modified Sun Lamp ("Microphotographic Lamp, 11 Volts") Which Avoids the Many Annoyances of Arc Lamps for Microscope Illuminators

AN INCANDESCENT lamp very similar to the sun lamp used for therapeutic purposes has been used by us in the metallographic laboratory of Cleveland Wire Works of General Electric Co. ever since 1931. It has so completely eliminated the disadvantages of the carbon arc for microscopic illumination that none of us would willingly go back to the old equipment. Notable among the deficiencies of the carbon arc are, of course, the periodic interruptions required to change the carbons, the fumes given off from the arc, the annoying fluctuations in position and intensity of the light source, and the necessity for using heat filters.

As seen by the illustration above, this sun lamp is somewhat special in that one of the electrodes is a ring and the other is a small cylindrical button of tungsten, whereas in the therapeutic lamp both electrodes are small cylinders of tungsten. This, of course, enables one cylinder to be the source of light and be placed in the optical axis of the instrument, shining through the adjoining ring. The resulting light is permanent, non-fluctuating, and has a photographic efficiency about the same as the 110-volt carbon arc. A small auto transformer, exactly the same as furnished with a therapeutic sun lamp outfit, is in series with the lamp across a 110-volt alternating current line. This transformer, when the switch is closed, strikes the arc at 30 volts, and as the lamp heats up, the voltage is automatically lowered to about 11 volts. At this time the lamp absorbs about 30 amperes of current and 330 watts of power.

With use the bulb gradually blackens by the condensation of volatilized tungsten from the electrodes, and the intensity of light is therefore gradually cut down. The efficiency may drop to about two-thirds in about 100 hr. steady use, and this is of importance to some photographic work. It can be used for visual examination in a metallurgical microscope much longer, perhaps three or four times as long. At any rate, we find in our operations — which are more or less intermittent — that a renewal of lamps every six to nine months is all that is necessary, and during this time it is not necessary to lengthen the photographic exposures owing to the decrease in lamp efficiency. Whatever loss in actinic value is experienced is more than compensated by the latitude of the photographic emulsion on the film. The cost of the lamps is consequently about equal to the cost of carbons in the carbon arc.

The normal method of operation of the lamp is with stem upward. It will, of course,

operate with the stem downward, but in that event the pool of mercury is so far distant from the arc that the current is largely carried by tungsten vapor rather than by mercury vapor. This causes the lamp to deteriorate very rapidly and runs the cost up correspondingly.

We have found some difficulty in using the porcelain socket, standard for the common therapeutic sun lamp. This has a large mass of heat-insulating material, and the metal parts in the socket become so hot they are covered with generous coats of oxide, and trouble will ensue with the contacts when it is necessary to renew a lamp. We have avoided this trouble by making our own socket, which is shown in the photograph. It is more highly ventilated, and because of this the metal keeps fairly cool.

Since this lamp is of a somewhat special design, it should be ordered directly from the Special Lamp Bureau, Nela Park, Cleveland, Ohio, by the following name: Microphotographic Lamp, 11 volts. Microscopes of American manufacture were exhibited at the last Metal Exposition with this method of illumination. It is, of course, a relatively easy matter to revise the illuminator of those older microscopes which still are using the bothersome arc lamp. Our mounting is shown in the accompanying view.

Ventilated Mounting Is Necessary for Sun Lamp When Adapted to Metallurgical Microscope, to Avoid Excessive Oxidation of Contacts

Correspondence

Copper-Lead Bearing Metals

Some Points on Automotive Practice

Dearborn, Mich.

To the Editor of Metal Progress:

The article in the August issue by Francis G. Jenkins on copper-lead bearing metals brings up several points in connection with a subject which is changing so rapidly now that individual viewpoints can readily be very diverse. For instance, Mr. Jenkins apparently holds the conventional view that the best structure for a bearing metal is probably that of a soft matrix with hard particles scattered through it. This view has been held by so many careful and competent metallurgists that one hesitates to controvert it, although it should be pointed out that the operation of a bearing is far from being a purely metallurgical matter, involving, as it always does, an adequate supply of a correct lubricant. Therefore, it seems very difficult to discuss bearings without getting over into the problem of lubrication, and, to my mind at least, an important characteristic of a good bearing material seems to be that it has a surface with the ability to hold a film of oil even though the pressure, speed and temperature of the rubbing surfaces be fairly high.

Mr. Jenkins notes the use of nickel as a dispersing agent in the casting of leaded bronze. The English view, as expressed by Mr. Neave in the abstract of his article from the *Journal* of the British Institution of Automobile Engineers on page 149 of the same issue, is that such addition agents should be kept as low as possible. I am inclined to agree with the English view. While it is admitted that nickel does aid in preventing lead segregation, it also causes the copper-lead bearing to score the crankshaft more readily than if the nickel is not there. Therefore, where it is possible to get a fine distribution of lead by chilling rather than by alloying, nickel would seem to be unnecessary, if not, in fact, undesirable.

The proper chilling of the copper-lead alloy is, in fact, a very difficult problem, and was the prime reason why the Ford Motor Co. abandoned the very interesting process which was described in *The Iron Age* for August 8, 1935. It is probably well known that the main bear-

Correspondence

ings on the Ford motor are lined with a loose bushing — that is, it is highly machined to close tolerances both inside and out and can rotate either on the crankshaft or on the connecting rod, or both. We found it very difficult to prevent lead segregating on one or the other of the surfaces, and for this reason as much as any other, we have replaced the copper-lead bearings with either cadmium-silver or cadmium-nickel bearings.

Finally, I would also cite another disadvantage of high phosphorus in copper-lead bearings, since it probably forms in a film between the copper-lead and the steel backing, causing a poor bond. This occurs when phosphorus is up to as high as 0.10 or 0.15%.

J. L. McCloud
Chemical & Metallurgical Dept.
Ford Motor Co.

Electric Pig Iron

Performance of Italian Shaft Furnaces

Turin, Italy

To the Editor of Metal Progress:

Owing to the excellent results obtained last year, both in Norway and in Italy, with electric furnaces for the production of pig iron, new plants of the same type are now being erected in Norway, Italy, Sweden and Finland.

Though the different local conditions, especially with regard to the quality of available fuel and ore, require special details of construction, and special metallurgical technique, all the new furnaces now under erection follow the principles of the original Tysland-Hole furnace, erected in 1928 at Christiania Spigerverk. Its essential principle consists in the use of long, continuous Soderberg electrodes, plunging very deeply in the furnace charge, so that the gases from the reaction zone preheat the charge and reach the top at a temperature as low as 400° F. Under these conditions, it is possible to close the furnace top and recuperate the gases completely.

Since all air is eliminated from the furnace, the gases bled off contain a very high percentage of CO (usually about 80%) and have a high thermal power (usually above 275 B.t.u. per cu. ft.). The average quantity of gas obtained is about 22,500 cu. ft. per short ton of iron produced. It is evident that a gas of such a quality is suitable not only for fuel but for a number of applications in the chemical industry, so that a convenient utilization of it is possible under practically all local conditions, for such things as organic syntheses, reduction processes, lighting, heating of furnaces or boilers, burning limestone, and so on.

Other great advantages, characterizing all the furnaces derived from the original Tysland-Hole design may be cited, such as the possibility of using cokes and anthracites of low quality for a reducing agent even though containing a high percentage of fines; constant composition of the iron produced, according to a predetermined analysis; ease of obtaining irons of almost any desired composition; low cost of installation, maintenance and repairs; low consumption of electrodes (usually between 16 and 30 lb. per short ton of iron, according to the composition of the latter) and power (from 2100 to 2750 kw-hr. per ton of iron, depending on the quality of ore and the analysis of product).

As the recent improvements in the Soderberg electrodes enable one to use larger and longer electrodes of high quality, there is now a tendency in Europe toward increasing the capacity of furnaces. A unit of 12,000 kva., with three electrodes on triangle, is now in operation in Finland, giving very satisfactory results. Even larger units are under erection in Italy.

A great advantage of the original Tysland-Hole principle for large units lies in the possibility of working with relatively high voltage (about 160 volts), and thus limiting the induction losses, which increase rapidly with the increase of the furnace size, other things remaining constant.

As I mentioned above, these developments have taken place under different conditions in different countries; consequently, the practical results obtained by the different plants also vary considerably.

As an instance may be quoted the results obtained with Italian furnaces smelting calcined pyrite with coke and making different types of pig iron. The fact must be taken into account that the calcined pyrite, after sintering, still contains more than 0.5% sulphur. Large quantities of slag must therefore be made, in order to maintain a percentage of sulphur in it low enough to avoid the inverse reaction, returning sulphur from the slag to the metal. The composition of the sintered pyrite ranges within the following limits: Iron 58 to 62%, silica 7 to 12%, and sulphur 0.7 to 1.5%.

Under these unfavorable conditions, using coke containing large percentages of fines, two main types of pig iron are produced: (Iron I) an iron for refining in steel furnaces, and (Iron II) an ingot-mold iron. The following are typical compositions:

Element	Iron I	Iron II
C	3.80 to 4.00%	3.80 to 4.00%
Si	1.00 to 1.50%	2.50 to 3.00%
Mn	3.10 to 3.50%	0.50 to 0.70%
S	0.006 to 0.030%	0.005 to 0.020%
P	0.025 to 0.040%	0.025 to 0.040%

An increase of the silicon content requires a higher power consumption. For Iron I the power consumption does not exceed 2200 kw-hr. per short ton, while for the production of a ton Iron II, 2600 kw-hr. are required.

Coke consumption (using a mixture containing two parts fine coke to one of lump coke, with 15% ash and 80% fixed carbon) does not exceed 800 lb. for a short ton of Iron I, and 900 lb. for Iron II. The average composition of dry furnace gas is: CO 77%, CO_2 15%, CH_4 1%, H_2 5% and N_2 2%. Four men per furnace are sufficient, even for the largest units.

Federico Giolitti
Consulting Engineer

Collection of Whatsits Picked Up in an Aluminum Foundry. The shapes are "as-spilled," the art work is "ad lib" (*Courtesy Aluminum Co. of America*)

Correspondence

Slag Inclusions in Steel

Standards for Size and Frequency

Schweinfurt, Germany

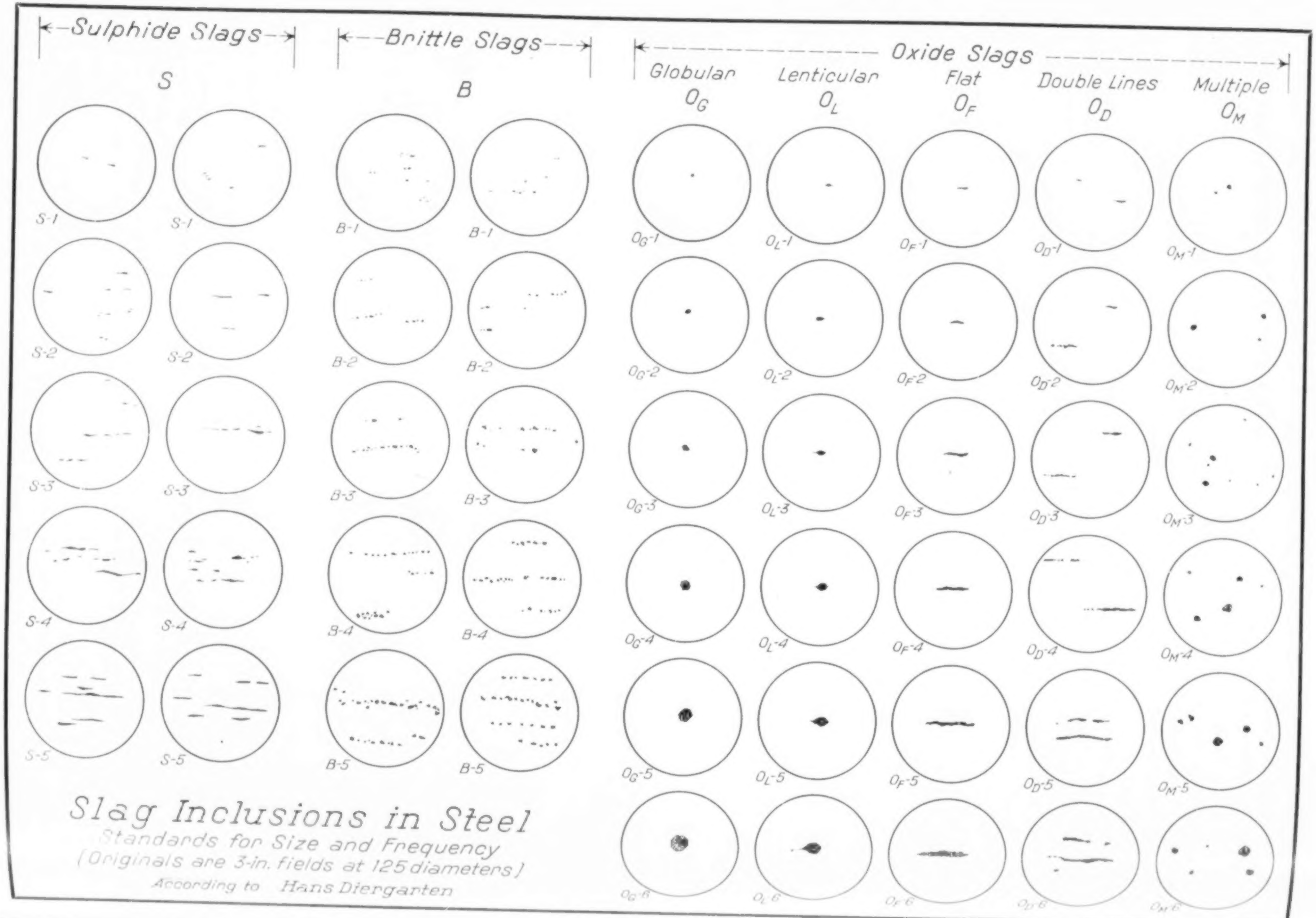
To the Editor of Metal Progress:

Slag inclusions vary in their effect on the useful properties of steel. In commercially good quality their presence in the steel usually has no effect on either the fabrication operations or the usefulness in service. In some steels, however, their size and number must be kept to a minimum. This is true of steels for anti-friction bearings. A large slag inclusion in either ball, roller or race will lead to premature fracture; the bearing will also roughen on the surface and therefore be noisy. For this reason the United Ball Bearing Co. (SKF) has been running extensive tests for a period of ten years to determine the size and type of slag inclusions allowable in anti-friction bearings. These studies have resulted in marked decrease in failures and an increase in service life.

A sufficient number of tests must be made in order to get a representative picture of actual conditions. A minimum of ten bars are taken from each shipment of steel. Samples are cut from one or both ends of these bars. Generally speaking, the number of test bars depends upon the experience we have had with the steel mill whose bars are under study, the size of the shipment, and our knowledge of the origin of each bar under test (ingot number, and position in the ingot).

To minimize grinding and polishing difficulties the steel should be hardened (this does not affect the slag inclusions) and the surface to be studied should always correspond with the direction of working. Machine polishing is quite suitable as long as low magnifications are used. Samples are generally unetched.

To obtain comparable results the magnification and, as far as possible, the field of view must be standardized. A magnification of 125 diameters into a field 3 in. in diameter we find quite suitable. When the inclusions are uniformly distributed a relatively short amount of time is required to examine the sample — say 1 to 1½ min. — and with large, isolated inclusions perhaps three times as long. It can be seen that one person working in a systematic manner can make a considerable number of observations at one sitting.



Slag Inclusions in Steel
Standards for Size and Frequency
(Originals are 3-in. fields at 125 diameters)
According to Hans Diergarten

Early in our studies the need for standards of comparison or "measuring stick" for the number and form of slag inclusions became apparent. Eventually seven columns of diagrams were devised, each vertical representing a certain type of inclusion and each horizontal row indicating the number and size of the inclusions. The result was a series of sketches rather than a series of photographs, and they are reproduced on page 270 (much reduced in size).

It should be remembered that this work was done on steels containing about 1.00% carbon and 1.50% chromium; other varieties of slags are found in steels of other types and our diagrams would therefore have to be augmented. However, as with the standard micros for this type of steel published in METAL PROGRESS in 1931 to 1933 by Styri and Walp of our American branch, these are applicable to all types of steel to a considerable extent.

Investigation of acid openhearth steels reveals a distinguishing group of grayish-blue inclusions designated as sulphides. These can be classified according to form, size, distribution and frequency under the two columns marked *S*; in any column No. 1 represents the smallest inclusions or groups of inclusions, No. 2 is next in size, and so on up to No. 5.

In all openhearth steel a second variety of inclusion is found which is designated brittle slags. These are mainly aluminum oxide. They occur in rolled or forged billets either at single points or ranged one close to another in one or more lines. These brittle inclusions occur not only in acid steels, but are also observed in slightly different form in openhearth steel made under other conditions of melting and pouring, and constitute most of the non-metallic inclusions in basic steel. In acid steels the inclusions are generally smaller, more numerous and more uniformly distributed in the ground-mass; the basic steels have a "cleaner" ground-mass and the more isolated inclusions are generally larger.

Acid electric steel, like acid openhearth, also contains mainly sulphide and brittle oxide inclusions as shown in columns *S* and *B*.

These two varieties, however, are not sufficient to classify basic electric steels. Besides the sulphides there exists only a little brittle slag; oxides exist mainly as larger inclusions in globular form O_G, lenticular form O_L or in flat areas O_F. Two more columns are necessary to complete the diagram — O_D, double lines of oxide inclusions, and O_M, multiple point inclusions. The consecutive numbers in all columns are

Correspondence

based on the increasing area of the inclusions.

It should be noted that all these forms are seldom found in one steel. Of the many varieties only a few established types are encountered in one steel plant, corresponding to individualities in the manufacturing practice such as charging, furnace practice, lining, melting, deoxidizing and pouring. Conversely, with a large number of samples it is possible to recognize the origin, history and quality of an unknown sample.

Basic open-hearth steels (high carbon-chromium steels, as in all the rest of this discussion) contain sulphide inclusions as in column *S*, which vary widely from heat to heat in size and frequency. They also contained "mixed inclusions" — that is, a dark oxide inclusion lying in a sulphide sheet. This type is prevalent in steels melted in the basic openhearth and finished in an acid furnace. Oxide inclusions of all the other types are likewise found. Indeed, basic openhearth inclusions are predominately of characteristic form and size, and require more than one symbol to characterize them — for example, O_F-6 plus O_G-5. With good melting practice basic openhearth steel contains fewer sulphide inclusions than acid openhearth.

Steels melted in the basic openhearth furnace and finished in the acid openhearth contain sulphide inclusions *S*, brittle oxides *B*, globular and lenticular inclusions O_G and O_L, and flat inclusions in single or double rows O_F and O_D, together with (at times) numerous mixed oxide and sulphide inclusions.

Inclusions observed in steels from the coreless induction furnace, acid lined, show no new diversifications in form, size and distribution. Size and number of inclusions vary considerably even in the same heat.

This diagram embodies a short and uniform method of estimating slag inclusions in practice. Even though it does not provide a scientifically accurate measurement and means of expression, it still presents a handy method for obtaining a clear conception of non-metallic inclusions in steel by means of a code. In any event, it eliminates the need for wordy descriptions or expensive photographs of individual cases.

HANS DIERGARTEN
Metallurgist
United Ball Bearing Co. (SKF)

Correspondence

67:33 Brass Sheet

Ratio of Hardness to Tensile Properties

KRAKOW, POLAND

To the Editor of METAL PROGRESS:

The well-known relationship between Brinell hardness and tensile strength of annealed steels can be used to secure an approximate idea of the strength when a tensile test cannot conveniently be made and yet a hardness test can.

Similar relationships for other metals are little known and little used. In our investigations on the influence of temperature and time of annealing on structure, hardness, tensile strength and elongation of 67:33 brass sheets, cold rolled to different degrees, we had occasion to collect a sufficient amount of data to determine this relationship: The tensile strength S_t in kg. per sq. mm. of a completely recrystallized sheet can be calculated from the Brinell hardness H_B, using the formula $S_t = 0.2\ H_B + 21$, with a tolerance of about $\pm$ 1.2 kg. per sq. mm. (To convert to lb. per sq. in. multiply S_t by 10,000 and divide by 7.) Furthermore, we determined that minimum elongation (gage length 10 times the width) in these sheets can also be calculated from the tensile strength by the formula $E = 120 - 2\ S_t$.

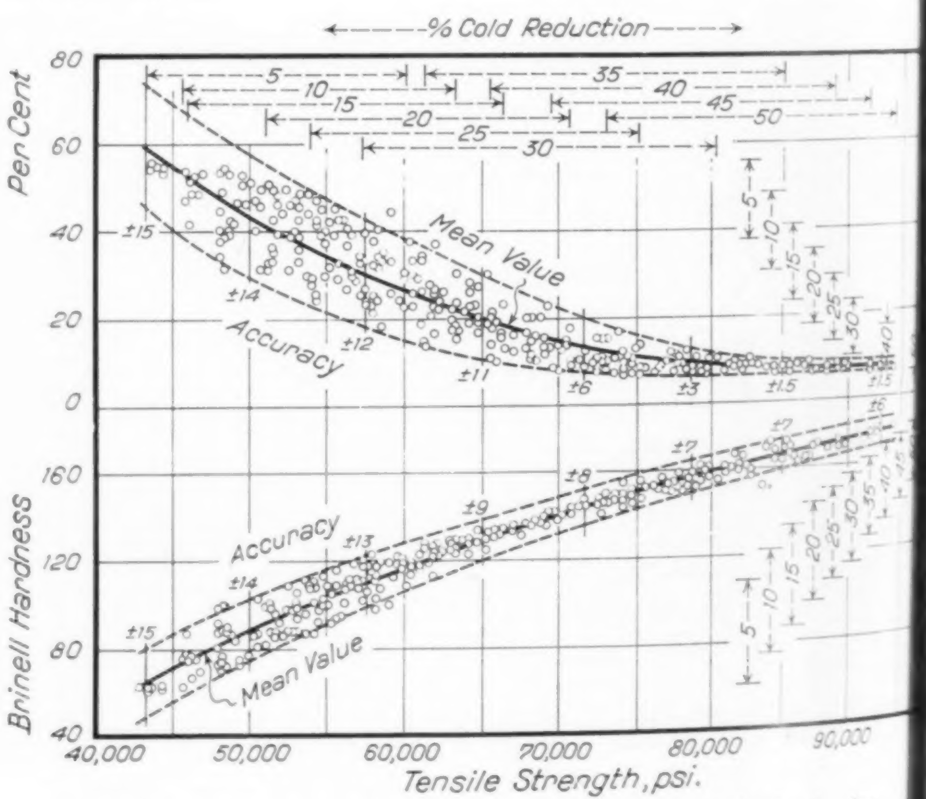
These relationships are only applicable to completely recrystallized sheets in which the primary grains have disappeared, and furthermore to those in which raising the annealing temperature increases only the grain size and changes the mechanical properties relatively little. These formulas have been verified only in the range of 45 to 110 Brinell hardness, 30 to 43 kg. per sq. mm. tensile strength (43,000 to 62,000 psi.), and 30 to 60% elongation.

In the course of another investigation carried out to determine the influence of primary structure and mechanical properties on the structure and the same properties after submitting to different rates of reduction in thickness, we concluded that there is no *linear* nor very precise relationship between such properties of work hardened sheets.

Our tests are plotted in the adjoining figure, which shows that the mechanical properties of various thicknesses, each having had the same amount of reduction, are not necessarily the same. (The numbers 5 to 50 on the "steps" of the diagram show the amounts of reduction and the corresponding limits of tensile strength, hardness and elongation.) This emphasizes the necessity for rigorous control of material to be fabricated into objects possessing definite properties, since the lack of uniformity of the mechanical properties of the material, even after identical operations, would confer different properties on the objects made.

We would also like to emphasize the effect of primary grain size on the mechanical properties obtained either after cold work or on the recrystallized sample. The temperature of initial recrystallization seems to be independent of the primary grain size — for a given annealing time — but recrystallization takes place more rapidly as the primary grain is smaller.

L. LOSKIEWICZ
General Metallurgical Institute
Krakow Academy of Mines



Ratio of Tensile Strength to Brinell Hardness (Below) and Reduction in Area (Above) in 67:33 Brass Sheet After Reduction by Various Amounts of Cold Rolling

Correspondence

Transverse Weakness in Forgings

Physical Properties of Heavy Crankshafts

DENAIN, FRANCE

To the Editor of METAL PROGRESS:

Large forgings offer metallurgical problems of importance, and these are intensified in such irregular shapes as crankshafts. In these it must be remembered not only that the properties in a transverse direction are affected by the degree of reduction, and that the response to desirable heat treatment is diminished by the mass of the pieces, but that the already delicate problem of fatigue resistance is complicated by concentrated stresses at changes of section and their application in a direction transverse to the "fiber." The effect of the last mentioned point is illustrated by the following test results:

Tensile strength of the given steel	100 (basis)
Fatigue limit in bending	
Smooth specimen	38 to 55
Small crankshaft	19 to 26
Fatigue limit in torsion	
Smooth specimen	24 to 36
Small crankshaft	15 to 23

Turning now to the more metallurgical aspects of the problem, let us first assume that we are able to get a sound ingot of well-made steel. It would take too long to discuss how sound steel is achieved, but we prefer acid open-hearth steels to basic. One important reason, among others, is that a statistical analysis of a large number of acid heats shows the "merit index" (tensile strength in kg. per sq. mm. plus twice the percentage elongation) to fall on a smooth probability curve of correct shape, whereas equivalent data from basic steel plot into a frequency curve lopsided on the lower side, and are therefore less consistently reliable.

Once having a sound ingot, the next thing to consider is the variation in physical properties found in the completed forging depending on whether the test piece is cut in a parallel, transverse, or radial direction to the axis. This effect is generally not noticeable in the tensile strength, but is evident in the ductility (as measured by elongation and reduction of area in a tensile test and by notched bar impact tests).

The literature on this subject of transverse weakness is now abundant. Any comprehensive discussion should commence with the dendritic segregation, ghost lines and other heterogeneity in the ingot, but a brief summary of the principal facts follows:

1. A metal possessing good mechanical properties before forging retains its superiority

Forging Machine Intended for Upsetting Operations on 14-In. Tubing. Twelve men can stand in its die box; its weight is about 250 tons. (Courtesy National Machinery Co.)

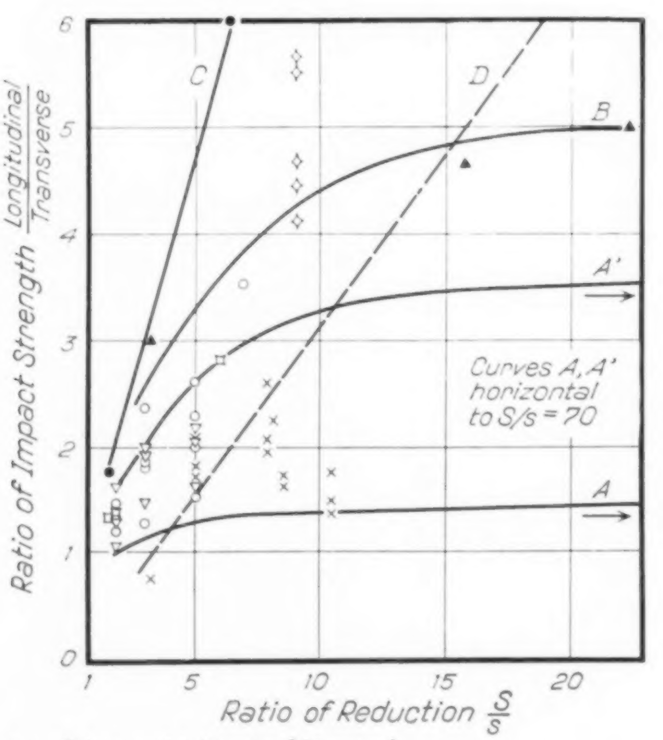
Correspondence

with regard to steels which were inferior to it in the cast condition.

2. Longitudinal ductility is superior to transverse, no matter whether the reduction $S \div s$ is light or heavy.

3. A forged structure has better tensile properties than the raw ingot. Therefore the longitudinal and transverse ductility both increase up to a certain limit (and then become stable) as the forging proceeds. Since longitudinal ductility increases more rapidly; transverse weakness increases up to a limit.

4. Exceptions to this rule are found in ingots of fine crystalline structure. A more general statement is that the ultimate degree of transverse weakness depends on the type of primary crystallization.



¤ 2-ton acid ingots [Charpy]
o 100-ton acid ingots [Maurer & Korshan]
v 40-ton basic ingots [Maurer & Gummert]
× 8 to 30-ton acid ingots [Delbart]
} forgings heat treated
✧ 30 ton basic ingots, mediocre [Delbart]

Curves A-A' Enclose Values Found by Voss for 2-Ton Ingots of Electric Alloy Steel (Ni-Cr and Cr-Mo), Excellent Quality, and Also the Values Published by Portevin, Prétet and Jolivet. Curve B is sketched for three results obtained by Descolas on 2-ton ingots of ordinary basic steel, and straight line C is between two similar values by Charpy.

5. As a corollary of 3 and 4, it is often necessary to set a minimum limit for the reduction of a coarsely dendritic steel in forging, in order to be sure to mitigate the irregularities therefrom.

6. Transverse weakness is the more noticeable after heavy forging if the original ingot was of inferior quality.

An attempt has been made to reduce the above qualitative statements into a quantitative expression in the attached diagram, where the ordinates are the reduction $S \div s$, ingot to forging, and the transverse weakness, or the ratio of longitudinal impact strength to transverse impact strength. Limiting curves *A* and *A'* are seen to enclose the values for ingots of excellent quality, as reported by a number of investigators. Several values for forgings from fairly large acid ingots, determined by the undersigned at Anciens Etablissements Cail, also fall within these limits; others for 30-ton basic ingots of mediocre quality are located above curve *A'*. Curve *B* for three forgings reported by Descolas, purposely made of very ordinary quality steels, also rests far above the limiting curve A' for good ingots. The line *D* on the diagram is intended to note the fact that the transverse weakness of forgings made from inferior steel will continue to increase as the amount of reduction increases, even far beyond $S \div s = 10$, where this ratio ceases to have further influence on the transverse weakness of forging steels of excellent quality.

Turning now to heat treatment, attention is directed to the second diagram, which is a somewhat generalized map of the variations in important mechanical properties of those steels used for large crank axle forgings. It should be obvious that a quench followed by a high draw (almost to the transformation temperature) gives very interesting and valuable properties, namely, a maximum ratio of fatigue to tensile strength $f \div T$, maximum impact strength *I*, and fatigue strength *f* only a little less than exists after lower draws (yet considerably higher than exists in the correctly annealed forging).

However, locomotive crank axles are parts of considerable weight and dimension, and the steels now favored are not as amenable to heat treatment as could be desired. These carbon and low alloy steels (nickel up to 2.5%, chromium up to 0.50%, and carbon up to 0.30%) harden only on the surface layers, and their interior structure retains a network of ferrite usually looked upon with disfavor and some-

times erroneously attributed to overheating. We made some experiments to clarify this point, on the axle steels shown in the tabulation, forged to 12-in. rounds.

After forging all pieces were annealed 3 hr. at 1560° F. and cooled in air (or in ashes for Steel D). At this point none of the steels had a network of ferrite; of course, they all possessed plenty of pro-eutectoid ferrite, but this was principally in separate areas in the fine granular microstructure.

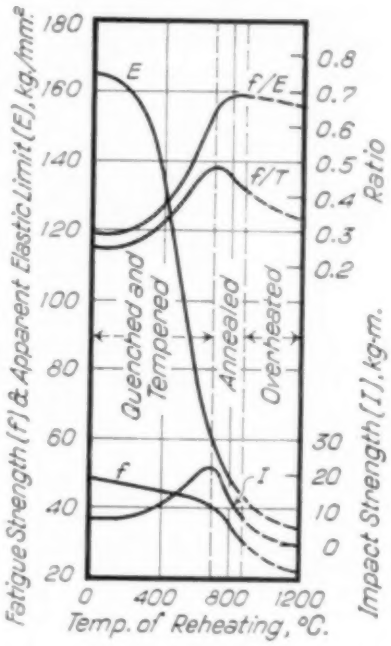
Sixteen-inch lengths of these 12-in. rounds were then quenched from 3 hr. at three temperatures, namely, 1560° F., 1655° F., and 1750° F. (water quenched, except Steel D in oil), and all pieces tempered 3 hr. at 1200° F. and cooled in still air.

After quenching and tempering a variety of microstructures were observed:

1. A homogeneous fine sorbite throughout the entire piece in Steel D (Ni-Cr-Mo).

2. The same for a surface layer 5 in. thick in Steel C (Cr-Mo). The central zone contained a few ferrite islands.

3. Sorbite showing traces of acicular orientation on the surface layers of Steel B (Ni-Cr) and at 3 in. below the surface and deeper the sorbite areas were outlined by interrupted networks of ferrite. Even deeper the structure appeared as in the central zones in the carbon steels.



Characteristic Curves Showing Relation of Physical Properties With Tempering Temperatures for Heat Treated Specimens of Forged Steels

Steels Whose Structure Was Studied

	Steel A	Steel B	Steel C	Steel D
Analysis				
Carbon	0.22	0.33	0.26	0.28
Silicon	0.31	0.29	0.21	0.16
Manganese	0.65	0.56	0.54	0.37
Phosphorus	0.026	0.021	0.030	0.034
Sulphur	0.026	0.013	0.016	0.010
Nickel		1.06		2.02
Chromium		0.50	0.52	1.07
Molybdenum			0.49	0.38
Reduction $S \div s$	8	10	8	5

Correspondence

4. The transition from sorbite to well-developed ferrite network in the carbon steel occurred in the outer 3 in. of the forging quenched from 1560° F., in the outer 1 in. of the forging quenched from 1655° F., and traces of the ferrite network appeared at the very surface of the one quenched from 1750° F. In all these the structure 6 in. deep and deeper was well-developed ferrite network with feathers entering the sorbite grains, very suggestive of overheated metal.

However, the difference in mechanical properties clearly differentiates the two varieties of microstructure. In overheated steels the properties are markedly lower than in the annealed state. On the other hand, the network structure in properly quenched and tempered steels is associated with improved transverse properties.

The following figures are each the average for five test pieces from the forgings under study; reduction of area is quoted because it is, in my opinion, the best indication of heterogeneity.

Heat Treatment		Carbon Steel A		Ni-Cr Steel B	
Quench	Temper	Impact	Red. of Area	Impact	Red. of Area
Annealed, 1560° F.		6.6	73	5.9	49
1560° F.	1200° F.	6.6	97	5.9	66
1655° F.	1200° F.	5.5	101	6.7	78
1750° F.	1200° F.	6.6	101	6.0	66

It is believed that the ferrite network reflects the size of the austenitic grain before cooling. Hence the grain size so indicated will be smaller in a shallow-hardening steel quenched slightly above A_3 than one badly overheated. Overheated steel also will possess more or less coarse pearlite if slowly cooled.

Engineering alloy steels with carbon less than 0.35% will, when properly annealed, normally possess a fine granular microstructure. This results from the decomposition of each austenite grain into several ferrite and pearlite masses, thus obscuring the grain size of the parent austenite.

Georges Delbart
Chief Metallurgical Engineer
Anciens Etablissements Cail

Incipient Fracture Revealed by X-Rays

By H. J. Gough

Abstract from Paper 34
International Association for Testing Materials, London, 1937

THE RESEARCH whose results are summarized arose directly from an extensive study of the deformation and fracture of metallic aggregates and representative types of single metallic crystals subjected to many diverse stressing systems. The method adopted in the previous work was the careful study of surface markings which, examined with the metallurgical microscope, were correlated with the applied stress system and the crystalline structure as determined by the ordinary methods of X-ray analysis. It was concluded that the initial submicroscopic crack which eventually led to failure was a direct consequence of slip on the substructure. In some manner, the structure became broken up into portions whose orientation differed appreciably from that of the initial structure. It appeared that severe local internal strains were somehow induced of sufficient magnitude to overcome the cohesive forces and lead to crack formation. To pursue the matter further in its essentials it was decided to employ precise X-ray diffraction methods with monochromatic rays in a systematic study of the changes produced in the crystalline structure by plastic deformation and fracture under various stressing actions and at various stages of these actions.

The material examined was a normalized mild steel. Each specimen was X-rayed before and after test; in many cases, several intermediate examinations were made. Five stress systems were employed: (1) Tension, (2) torsion, (3) alternating tension and compression, (4) repeated tension, (5) alternating torsion.

Whatever type of stressing was applied — torsion, tension, compression — and independently of the nature, whether static or cyclic, the effect on the crystalline structure is one of destruction of the crystals, leading to the material being always in one or more of three conditions: *(a)* Perfect grain, giving a sharp X-ray reflection, having the same orientation throughout and a grain size of approximately 10^{-2} cm. (0.004 in.). This is the original condition of the steel. *(b)* Dislocated grain, giving a reflection which is elongated along the ring, consisting of fragments oriented to each other at angles not exceeding 2°. *(c)* Crystallites. These are *very* small crystal fragments giving reflections in the form of a sharp line extending further round the ring than that due to a dislocated grain. The grain size of these crystallites is of the order of 10^{-4} cm. to 10^{-5} cm. (0.00004 to 0.000004 in.); they have entirely random orientation. In an X-ray photograph, a "tail" attached to a strong reflection from a dislocated grain indicates that some widely oriented crystallites form simultaneously when a perfect grain is dislocated, probably at the boundaries of the dislocated grains.

Within the elastic range these studies indicate no change in structure, from the perfect grains, if the stressing is "static." Between the elastic limit and the yield point a few perfect grains break up, forming a small proportion of dislocated grains and crystallites. After passing the yield point every perfect grain is broken up into dislocated grains and a large number (even though a very small volume) of crystallites. Under increasing stress, the process of dislocation proceeds with the production of a larger proportion of crystallites. At fracture the metal consists *entirely* of crystallites oriented at random. At this stage the diffraction ring in an X-ray photograph broadens, which probably indicates strain distortion of the atomic lattice; fracture probably occurs when this distortion reaches a limiting value.

A different sequence of events occurs under fatigue stressing. Two factors are of major importance, the maximum stress of the cycle and the range of stress. At the *first* application of the maximum stress, some damage, by break-up, is caused to the structure; this damage may vary from zero to any value of destruction according to the extent by which the maximum stress exceeds the yield point. This initial damage may be confined to the first cycle or may be spread over a number of cycles; this depends on the cyclic frequency, due to the effect of high cyclic speeds on the suppression or delay of plastic movement. In either case, the safe range or fatigue limit is the maximum range which will cause no further *progressive* break-up; once the *(Continued on page 282)*

Personals

A. Allan Bates, professor of metallurgy at Case School of Applied Science, Cleveland, has been made manager of the chemical and metallurgical division of Westinghouse Research Laboratories, East Pittsburgh.

R. P. Donnell has resigned from Aviation Mfg. Corp. to become chief metallurgist at White Motors Co., Cleveland.

Charles H. Jennings, engineer in charge of welding research for the Westinghouse Electric & Mfg. Co., has taken a three-months' leave of absence to act as consulting welding engineer for the English Electric Co. in England.

Peter A. Vukmanic, graduate student at Carnegie Institute of Technology, has been awarded the Robert Tillman Memorial Graduate Fellowship in Metallurgy.

Ralph K. Clifford, formerly general superintendent, has been appointed works manager of the Kokomo branch of Continental Steel Corp. **Julian L. Schueler**, formerly superintendent of the Steel and Wire Division, has been named general superintendent.

Carl H. Samans has resigned his position in the Metallurgical Department of the Rensselaer Polytechnic Institute to become assistant professor of metallurgy in the School of Mineral Industries of Penn. State College.

Harry P. Coats of the Firestone Steel Products Co., Akron, Ohio, has been awarded the gold medal of the American Electroplaters' Society for the best paper on electrodeposition during 1936.

Johnston Kingsley is now employed in the Crescent Laboratory of the Crucible Steel Co. of America, Pittsburgh.

John E. Shoemaker has left the Youngstown Sheet & Tube Co. to become metallurgist for the Bundy Tubing Co., Detroit.

Russell Bernt is now employed as a metallurgist in the Engineering Laboratories of the Frigidaire Division, General Motors Corp., Detroit.

N. U. Stryker, formerly with Illinois Tool Works, has joined the Claud S. Gordon Co., Chicago.

F. W. Johnston, formerly graduate assistant in the Mechanical Engineering Department, Oregon State College, is now employed in the Testing Laboratory of American Gas Association, Cleveland.

Ralph Schaper left Pelton Steel Casting Co. to become head of the Inspection Department at Smith Steel Foundry Co. in Milwaukee.

Charles A. Conlin, formerly with Latrobe Foundry & Machine Co., has accepted the position of plant superintendent of the Brighton Electric Steel Casting Co., Beaver Falls, Pa.

E. E. Samson is now assistant to the managing director of the Electric Institute, Washington, D. C.

Personals

James R. Long, formerly instructor of metallurgy at Pennsylvania State College, is now assistant professor of chemistry and metallurgy at the U.S. Naval Academy, Post-Graduate School.

H. E. Hostetter has resigned as research assistant with the American Rolling Mill Co. to accept the position of metallurgical engineer with the Research Laboratory, Climax Molybdenum Co. of Michigan, Detroit.

Edgar H. Howells has been made research engineer in the Development & Research Department of Bethlehem Steel Co.

G. W. Stickley has been transferred to the Aluminum Research Laboratories, New Kensington, Pa.

Robert M. Phillips, formerly instructor at Case School of Applied Science, has joined the metallurgical department, Aluminum Co. of America, at Massena, N. Y.

Henry E. Sanson has been made sales manager, Eastern Division, of E. F. Houghton & Co.

Robert L. Wagner is now employed by W. R. Grace & Co. as assistant to the foreign sales manager of Traylor Engineering & Mfg. Co.

Otto W. Winter has been appointed factory manager of the Columbus McKinnon Chain Corp. of Tonawanda, N. Y.

E. L. Robinson, formerly research engineer, Westinghouse Electric & Mfg. Co., is now employed in the Metallurgical Department, Farrel-Mercer Works of Carnegie-Illinois.

Edward G. Jennings is now metallurgist for the Canadian Bronze Co., Ltd., Montreal.

H. Wilbur Paret, Jr. has been made sales engineer for the Pittsburgh district, The Selas Co.

G. A. Reifsnyder has accepted the position of metallurgical engineer of the Rotary Electric Steel Co., Detroit.

J. R. Hall is now employed as an engineer by the Cribben & Sexton Co. of Chicago.

R. J. Perry, formerly tool hardener for Nordberg Mfg. Co., Milwaukee, is now employed as service man with Boyd Wagner Co., Chicago.

Ed W. Smith, formerly of the Pittsburgh Steel Co., has joined the Bethlehem Steel Co. in the Sales Division.

Edwin C. Yaw, formerly graduate assistant, University of Rochester, is now with Thermal Engineering Corp., Richmond, Va.

Lewis Gelbert has left Inland Steel Co. to become metallurgist at U. S. Metals Refining Co., Carteret, N. J.

A. R. Kommel, formerly research assistant, Carnegie Institute of Technology, is with the research laboratory, United Engineering and Foundry Co., Vandergrift, Pa.

George I. Calvert, formerly metallurgist for Carnegie-Illinois Steel Corp., is now metallurgist for The Texas Steel Co.

Incipient Fracture

(Cont. from page 276) initial stage is completed, no change is caused by any number of cycles of a safe range of stress.

If the applied range of stress exceeds the safe range, progressive deterioration and break-up into crystallites sets in, leading to fracture exactly as in a static test to destruction. The greater the range of stress, the greater the total number of perfect grains completely destroyed and the fewer the number of cycles required to produce complete fracture, but the same destroyed structure is reached in the immediate neighborhood of the crack.

Thus these experiments afford a physical explanation of the form of the familiar S-N fatigue curve and of the fatigue process. In addition, they show clearly that the fracture of metals under static and fatigue stressing is accompanied by exactly the same changes in structure; the only difference is that static stress rapidly affects all the grains, whereas cyclic stress may cause less uniform destruction by concentrating on a proportion of the grains, the proportion increasing with the range of stress.

The appearance of dislocation in a grain, now experimentally established, under stresses less than those theoretically required to produce deformation is not inconsistent with the recent theories of slip mechanism propounded by Taylor, Orowan and Polanyi, and offers some indirect evidence of an inherent system of flaws in metallic crystals. It may be fairly claimed that the common condition at fracture, irrespective of the type of applied stress, represents a definite simplification of our views about the mechanism of fracture. Further, the limiting size of the crystallites formed from the grains at fracture raises a point of great interest; from X-ray work on metals deformed by cold work it has been suggested that the limit corresponds to an equilibrium between fragmentation and the inherent tendency to recrystallize arising from thermal agitations. Further, it would appear from the present work that the existence of the dislocated grain in the medium of more perfect grains represents a potential flaw leading to initiation of the submicroscopic crack and the first stage in fracture; the increase in the formation of dislocated grains observed when the cyclic stress range is increased enhances the probability of an effective crack, the S-N curve being essentially a probability curve.

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Advances in Aluminum Alloys in England

By S. L. Archbutt and A. G. C. Gwyer

Abstract from Papers 55 and 56, International Association for Testing Materials, London, 1937

WHEREAS 12 years ago it could be said that duralumin was the only wrought aluminum alloy on a commercial basis of production in England, today a wide choice is available. This progress has followed the application of results of research into the mechanism of the spontaneous hardening after quenching (age hardening), into grain refinement and corrosion, and particularly into the solubility of constituents in the solid alloys, on which hardening after quenching has been found to depend.

Several wrought alloys with useful properties and moderate strength may be mentioned. Those containing magnesium (5 to 10%), with or without a small amount of manganese, possess good ductility with remarkable resistance to atmospheric and marine corrosion. Alloys with silicon (8 to 12%) are highly ductile.

A very useful alloy has small amounts of magnesium and silicon in proportions obtaining in the compound Mg_2Si. In the hot-worked or annealed condition it can readily be formed into various shapes and afterward hardened by simple heat treatment to give a tensile strength of 52,500 psi. with 9% elongation in 2 in. Owing to its excellent electrical conductivity (90% approximately of that of aluminum), lightness, and strength, it has proved valuable for overhead electrical transmission lines.

Another medium strength alloy contains 4 to 5% copper and small amounts of silicon and manganese. In this aluminum alloy the variable solubility of the compound $CuAl_2$ is made use of to obtain hardening by heat treatment after quenching. In sheet form a tensile strength of 57,000 psi. with 15% elongation in 2 in. is obtained.

Even stronger alloys have been developed. By slightly altering the proportions of the constituents of duralumin, it may be hardened still further (by suitable heat treatment after the spontaneous hardening which normally follows quenching) to a tensile strength over 67,000 psi. with 10% elongation in 2 in. *(Cont. on p. 288)*

★ ★ ★

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Aluminum Alloys

(Starts on page 286)

Still higher strength follows spontaneous hardening after heat treatment of an aluminum alloy containing 2.5% copper and 20% zinc, to which small amounts of magnesium and manganese were added. A tensile strength up to 90,000 psi. with 10% elongation in 2 in. was obtained from rolled rod. This alloy, unprotected, is very sensitive to corrosion and approximately 10% heavier than duralumin. Though successfully produced in sheet form on a commercial scale in a Government airship works during the War, it has not been taken up by industry.

For strength at high temperatures for purposes such as forged pistons and cylinder heads of aircraft engines, an alloy containing 4% copper, 2% nickel, 1.5% magnesium, developed during the War, has proved very satisfactory. At room temperature the alloy gives 58,000 to 62,500 psi. tensile strength with 18 to 25% elongation in a forged bar, spontaneously hardened after quenching. About half this strength is obtained in a short time tensile test at 650° F., compared with one-third for duralumin. By altering the proportions of the constituents and adding a small amount of titanium (which refines the grain in cast aluminum alloys) another valuable series of alloys has been produced with similar mechanical properties together with a high proof stress.

There are demands for alloys with a greater ratio of strength to weight at atmospheric temperature, and greater strength at elevated temperatures, the latter by reason of the continual rise in operating temperature of internal combustion engines for high speed aircraft.

Recent progress in cast aluminum alloys in Great Britain, as is the case elsewhere, can be looked at from two points of view — the introduction of new or improved alloys and additional or increased uses of either established or new alloys. Among the new aircraft specifications are alloys in which cerium replaces titanium as the grain-refining agent; another alloy of similar type contains chromium.

A new specification covers "Aeral," a heat treated alloy containing cadmium, added to improve corrosion resistance by its cathodic action; the alloy also has outstanding machinability. A heat treated aluminum-copper alloy containing magnesium is also covered by a new specification, *(Continued on page 292)*

Help Yourself

to this

HELPFUL LITERATURE

Instrument Slide Rule

An ingenious slide-rule indicator devised by Westinghouse Electric & Mfg. Co. selects the proper instruments for any application, whether central stations, industrial plants or transportation industry. It shows at a glance what instruments to use, their range, approximate price, size, and descriptive literature available. Bulletin Ia-134.

Chromel

A new catalog has been issued by Hoskins Mfg. Co. covering Hoskins electric furnaces and Chromel elements, which provide uniform heat and automatic temperature control with excellent production and quality of work. Bulletin Ia-24.

Tempering

Vertical batch type tempering furnaces are described in a folder by Industrial Heating Equipment Co. Capacity and production figures and a diagram of the furnace are included along with a complete description. Bulletin Ia-168.

Pipe Lines

Latest information on the construction of pipe lines by electric welding for transportation of oil, gas and water is contained in a bulletin by Lincoln Electric Co. Fourteen pages, profusely illustrated. Bulletin Ia-10.

Seamless Tube

Excellent illustrations are combined with clearly written text to portray the wide variety of seamless flexible metal tubing made by American Metal Hose Branch of the American Brass Co. Bulletin Ga-89.

Instrument Information

C. J. Tagliabue Mfg. Co. has a 56-page book on indicating and recording temperature and pressure instruments which is more than a regular listing catalog, for it presents information in a clear, understandable way on the latest Tag developments, many of which have never before been published. Bulletin Ia-62.

Monel for Screens

Convincing and interesting is a handsomely printed and illustrated bulletin by International Nickel Co. covering the properties and applications of monel metal in wire screen and filter cloth. Bulletin Ia-45.

Scale-Free Hardening

General Electric scale-free hardening furnaces for either large or small volume of production, ferrous or non-ferrous applications, box or continuous type, are accurate and automatic. Described in Bulletin Ia-60.

Explosion Protection

A gas burner safety device designed to prevent explosion made by Wheelco Instruments Co. is known as the Flame-otrol. Illustrations, data, operating diagrams and prices are fully covered in Bulletin Ia-110.

Cement

"Hytempite" is a high temperature cement for laying up firebrick with thin, long-lasting, air and gas tight joints of great strength, made by Quigley Co. How it saves time and labor and cuts construction and maintenance costs is told in Bulletin Ia-139.

Contour Sawing

A complete handbook covers this interesting machine operation using narrow band saws and files. Contour sawing technique and its myriad applications are described. Continental Machine Specialties Co. Bulletin Ia-170.

CO_2 Meter

Attractive and complete is Brown Instrument Co.'s catalog which covers the full line of Brown indicating and recording CO_2 meters as well as the combined CO_2 and flue gas temperature recorders. Bulletin Ia-3.

Laboratory Furnaces

Specifications, description and uses of a muffle furnace with transformer and rheostat and a multiple unit furnace with controlling pyrometer for laboratory or light tool room work are given by Hevi Duty Electric Co. Bulletin Ia-44.

Electrical Sheet

Published with the title "USS Electrical Steel Sheets," a new booklet embodying the latest factual information on this specialty product has been released by the Carnegie-Illinois Steel Corp. Bulletin Ia-79.

Furnace Parts

A valuable feature of Driver-Harris Co.'s folder on Nichrome cast furnace parts is a table giving the tensile strength of Nichrome castings at various temperatures. Bulletin Da-19.

Pickling

All current pickling procedures and practices were carefully studied, analyzed, summed up and compared in the preparation of a 32-page handbook on pickling steel with modern inhibitors by E. F. Houghton & Co. A frank, instructive manual. Bulletin Ia-38.

High Frequency

The well-known Ajax-Northrup electric furnaces are excellently catalogued in a 22-page book, which covers all sizes and types for laboratory or shop. Includes illustrations, diagrams, tables and charts. Ajax Electrothermic Co. Bulletin Ia-41.

Pyromaster

Bristol Co.'s "Pyromaster" is a recording potentiometer with a round chart and direct ink marking. Its applications as a pyrometer, resistance thermometer, tachometer and millivoltmeter are given in Bulletin Ia-87.

Kanthal Alloys

S.K.F. Steels, Inc., offer a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

Tool Steel Selector

A wall chart, 30 x 20 in., to be used as a means for selecting the proper type of tool steel is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jz-12.

Rustproofed Steel

Atmosphere does not corrode steel which has been rustproofed with Duozinc, a mercury-containing zinc anode with marked production properties. Full details are given in a folder issued by the R. & H. Chemicals Dept. of duPont. Bulletin Ar-29.

Locomotive Steels

A comprehensive review covers specific applications, based on current practice, of various types of vanadium steels for locomotive and car construction. It contains 72 pages and is available to railway executives and engineers. Published by Vanadium Corp. of America. Bulletin Dy-27.

Cutting Oils

The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jy-118.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

Air Weight Control

An illustrated booklet of sure-fire interest to the foundry trade has been issued by The Foxboro Co., explaining in detail the advantages of the "air weight controller" which is in use at many of America's leading foundries, named in the publication. Bulletin Ea-21.

Automotive Furnaces

Nowhere does heat treating play a more essential part than in the construction of the motor car. Gas-fired heat treating furnaces designed especially for use by the automotive industries are illustrated and described in a booklet by Surface Combustion Corp. Bulletin Ia-51.

Corrugated Ingots

The Gathmann Engineering Co. has published a new booklet called "Gathmann Ingot Molds — Their Purpose and Design." It illustrates various corrugated ingot contours designed to produce defect-free surface in steel ingots. Bulletin Ay-13.

Compressor Data

General information on the application of blowers to gas and oil burners, and miscellaneous applications for other types of work are included in a 12-page "Turbo-Compressor Data Book." Useful tables and charts are included. Spencer Turbine Co. Bulletin Dy-70.

Camera-Microscope

A highly efficient and up-to-date apparatus that is an ingenious combination of several instruments into one universal camera-microscope is described by Pfaltz & Bauer, Inc., in a handsomely printed booklet containing some intriguing photomicrographs. Bulletin Oy-142.

Abrasive Cleaning

Comprehensive information on airless abrasive metal cleaning is contained in a new book on the "Wheelabrator" Tum-Blast, a patented mechanical device made by the American Foundry Equipment Co. Bulletin Fa-112.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Insulating Brick

Drawings of 12 modern types of industrial furnaces for which Johns-Manville's new JM-20 insulating brick has been developed are contained in a folder which also carries a useful table giving heat losses transmitted through bare and insulated firebrick walls. Bulletin Ia-100.

Spectrographs

A new catalog has been prepared which gives complete details of the Bausch & Lomb line of spectrographs and accessories, from small units to the large Littrow spectrographs with "matched" accessories, to satisfy the most exacting needs. Bulletin Ay-35.

Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

Grinding Carbides

A complete and detailed treatise on this important problem has been issued by the Carborundum Co. Special wheels and grits for the various commercial grades of carbides are given and many practical pointers are included. Bulletin Nv-57.

Some of the Best Thinking

in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.

Water Supply

Modern design, sturdy construction, compact size, and light weight are stressed as features of the water systems and pumps built by Roots-Connersville Blower Corp. Described in Bulletin Ga-131.

Radiation Tube

The Pyrometer Instrument Co. has a super-sensitive radiation tube for high temperature readings where thermocouples are unreliable or too expensive. This rapid recorder is described in Bulletin Fa-37.

Silver Solder

The results of both laboratory and actual production data are contained in a booklet by Handy & Harman which includes detailed instructions and two pages of hints on the subject of soldering and brazing with silver alloys. Bulletin Ay-126.

Flowmeters

Flowmeters patented by American Gas Furnace Co. measure the entire flow of air or gas, thus permitting exact control of gas burning operations and carburizing. The principle, installation and uses are described in Bulletin Ha-11.

Hy-Speed Case

50 to 500% increase in the life of high speed steel tools is claimed in a striking and interesting new booklet just published by the A. F. Holden Co. Typical cases of these savings are cited. Bulletin Fa-55.

Testing Equipment

Fully illustrated, complete with charts, curves and other technical data, containing 48 pages, and in two colors throughout, the new Testing Machine Bulletin issued by the Baldwin-Southwark Corp. containing a comprehensive description of the well-known Southwark-Emery line of equipment should be a valuable addition to any library. Bulletin Ha-67.

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-169.

Metallograph

Leitz Large Micro-Metallograph "MM-1" — most interesting 36-page publication containing numerous photomicrographs on the very latest developments in metallographic equipment. Special attention is given to darkfield illumination. Bulletin Ha-47.

New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive non-oxidizing furnace atmosphere and their new, continuous brazing, copper and soldering furnaces. Full details are given in Bulletin Ar-30.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Oxidation

Designers confronted with oxidation problems connected with cracking coils, polymerization plants, superheaters, high pressure steam plants, air heating equipment and recuperators will welcome a folder by Timken Roller Bearing Co. containing data on oxidation at 1000, 1250 and 1500° F. Bulletin Ea-71.

Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

Meehanite

A compact but complete specification chart gives the recommended grades of Meehanite metal for various service requirements. Complete physical properties and applications are included. Bulletin Da-165.

Cutting Steel

Recommended practices for gas cutting of structural steel are given in a concise and authoritative form by The Linde Air Products Co. Qualification tests for good workmanship from the standpoint of accuracy and smoothness of cuts are also described. Bulletin Dc-63.

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue — Bulletin Ax-4.

Chapmanizing

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Alcoa Notes

"Alcoa Random Notes" is the intriguing title of a little monthly paper got out by Aluminum Co. of America. A request for this bulletin will bring you a copy of the latest issue. Bulletin Ca-54.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Blast Cleaning

So many changes have taken place in blast cleaning and dust collecting equipment in the past three years that Pangborn Corporation's "quick reference" catalog of condensed information will be invaluable to all those interested in this subject. Bulletin Jy-68.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Copper Bulletin

A new clearing house for news of developments in brass, bronze, and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Laboratory Service

A new edition of "The Metal Analyst" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Hump Hardening

All three vital factors in correct hardening are completely controlled by the new Vapocarb Hump method of hardening, which is well described in a Leeds & Northrup bulletin. The three factors are: Quench point, rate of heating, and furnace atmosphere. Complete details are given in Bulletin No-46.

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Ia-24	Ia-170	Jz-12	Dy-70	Fa-37	Oy-147	Ar-64	Da-163
Ia-168	Ia-3	Ar-29	Oy-142	Ay-126	Ea-71	Ca-54	Jy-125
Ia-10	Ia-44	Dy-27	Fa-112	Ha-11	Oy-81	Fx-66	Dy-135
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Ia-110	Ia-87	Ia-51	Nv-57	Ar-30	Ax-4		

Aluminum Alloys

(Starts on page 286)

as are also some heat treatable silicon alloys. These latter are of two types, a high silicon (13%) and a low silicon (5%) alloy. They depend on the presence of magnesium for their improvement by heat treatment.

The only non-heat treated alloys covered by new specifications are a modified silicon alloy of medium silicon content and a silicon alloy containing nickel, which improves the elastic and dynamic properties.

From the above list the outstanding points are the increasing use of heat treated alloys, the use of grain-refining agents, and the progress of the heat treatable silicon alloys. Heat treated alloys are favored on account not only of their increased strength, but because the ratio of proof stress or elastic limit to the ultimate tensile stress is raised, while the ductility and toughness are superior to those of as-cast alloys.

The heat treatable silicon alloys are really the chief new alloys and they show definite advantages over some of the other heat treated alloys. They are easier to cast, give less trouble in the foundry, and seem less liable to develop internal cracks and strains on quenching from high temperatures.

Many of the new alloys used in England are not covered by official specifications; this does not imply that they are not largely used, but that they have found their chief uses in other purposes than aircraft parts such as:

1. High silicon alloys with a relatively low thermal expansion, largely used for automobile pistons rather than for larger internal combustion engine pistons. These alloys can also be anodically oxidized by the cheapest process.

2. A tendency to use cast alloys with a low total content of alloying elements, in order to obtain as high a corrosion resistance as possible and a satisfactory match, when anodized, with pure or wrought alloys. An alloy containing 1.25% Mg and 0.7% Si is an example of this type. Such alloys present foundry difficulties from high shrinkage, and they are not very strong in the as-cast state.

3. There is some use of magnesium or magnesium-manganese alloys in the as-cast state. These have a superior corrosion resistance and reasonably good mechanical properties. The high magnesium heat treated alloys have not made much progress.

4. Alloys containing from 6 to 10% Si have made considerable progress; with the lower silicon contents they do not revert rapidly from the modified to the normal state and they have good ductility and casting properties. *(Cont. on p. 298)*